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MULTIDISCIPLINARY ANALYSES OF SKYLAB PHOTOGRAPHY FOR HIGHWAY ENGINEERING PURPOSES

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16. Abstract A background of highway-related disciplines utilizing airphoto interpretation is outlined. LANDSAT-1 investigation results for geomorphology, hydrology, and vegetation damage reports are summarized. The visual aspects of SKYLAB photography i.e. photo interpretation methodology, and multistage study and comparisons with LANDSAT imagery and conventional aerial photography are the prime means of study and data extraction. SKYLAB coverage of the State is somewhat limited; studies were tailored to the available photography. Highway-associated vegetation damage sites were limited within the study region, but significant damage areas of other types were identified. Resolution of CIR film was not adequate for the delineation of small damage sites. Areal extent of damage must be extensive to be detected. A single large watershed was studied in detail, using four SKYLAB films, U-2 aircraft photography and LANDSAT imagery. Vegetation cover types and ridge line delineations are compared and relative values of media analyzed. The use of SKYLAB photography for land use typing is feasible. Detailed studies of glacial landforms (geomorphology) were made of two select areas in regions of diverse morphology. Detailed and generalized maps are included that show features identified on SKYLAB and other media. The synoptic coverage of eastern Maine revealed possible new correlation data. S190B photography is superior to S190A, and both are better than ERTS imagery for hydrologic and geomorphic studies. No summer S190B was available for vegetation damage analysis. An appendix of film evaluations by field personnel is included.			
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PREFACE:

The objectives of this multidisciplinary study are to analyze and evaluate SKYLAB photography by visual methods for potential highway engineering purposes and applications, and to compare the relative data extraction potentials of the various film types with other very small scale remote sensing media, namely LANDSAT-1 imagery and U-2 aircraft photography. The three major disciplines of study are (1) the detection of highway-associated vegetation damage sites, and their causes, (2) the detection and identification of significant hydrologic parameters for drainage study applications, and (3) the detection and identification of surficial granular formations for inclusion in materials inventory reports of highway construction materials sources.

The scope of work performed includes the detailed study of all SKYLAB photo products by photo interpretation methods. Analyses were made of 70mm and 4.5-inch format transparencies, NASA-supplied transparency and paper print enlargements and in-house produced enlargements. Because of limited coverage of Maine by SKYLAB photography, study sites were tailored to locations having suitable coverage and existing ground truth data. Only late summer S190A photography was available for the study of Western Maine surficial geology. In eastern Maine, winter coverage by S190A and S190B was available for surficial geologic studies. Cloud cover obscured a large portion of southern and central Maine during this single winter orbit pass. Comparisons were made of SKYLAB, LANDSAT-1 and U-2 film and imagery.

Conclusions: S190B film from the Earth Terrain Camera provided the best media for stereo viewing and evaluation for all disciplines, and is considered second only to U-2 RC-10 photography. S190A films performed

very well for certain discipline studies and are considered generally superior to LANDSAT-1 imagery for the identification of terrain features. S190A CIR summer coverage is not adequate for the detection of vegetation damage sites of the small size generally associated with highways. Land use and vegetation cover types are best detected on S190B film, and S190A films are generally better for this discipline than ERTS imagery. (Refer to Table V, page 61). Winter SKYLAB film is superior to LANDSAT-1 imagery of any season for the study of surficial geology, and winter S190A color and Panatomic-X are better than S190A CIR.

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Ernest Stoeckeler, head of the M.D.O.T. airphoto section, died on April 8, 1975, following a long illness. A pioneer of airphoto interpretation in Maine, he envisioned the utility of satellite imagery and photography for the long range planning of highway engineering disciplines. It was through Ernie's efforts that the study of ERTS-1 (LANDSAT) and SKYLAB imagery was made possible. What he learned and taught to others during his active and productive career will stand as a fitting memorial to his contributions to the science of remote sensing.

BACKGROUND AND INTRODUCTION

General

Remote sensing of terrain and vegetation features is an important consideration in the compilation of preliminary location, design and materials data by the Maine Bureau of Highways.¹ Interpretation techniques utilizing conventional aerial photography have been applied to studies and investigations in several disciplines associated with highway engineering for about twenty-five years. Engineering soils maps were first prepared on a 15-minute quadrangle basis in 1950. Since 1956 with the development of the Interstate Highway System, strip maps indicating soil engineering characteristics have been prepared for most major relocation projects. Investigations of granular sources have been initiated by remote sensing procedures since 1954, with materials inventory reports prepared for all major highway studies. Since the mid-fifties, again instigated by the Interstate System, several thousand watersheds adjacent to proposed reconstruction projects have been evaluated by photo interpretation methods for highway drainage studies, with a minimum amount of field checking.

Environmental impact statements, now required for all Federally funded projects, are receiving progressively increased input of remotely sensed data. A study started in 1970 of damaged vegetation associated with highways and highway facilities may be regarded as a forerunner of environmental investigations in Maine.

¹The Maine State Highway Commission became the Bureau of Highways within the Maine Department of Transportation, July 1, 1972.

Three proposals for investigating LANDSAT-1 imagery, submitted to NASA in April of 1971 were eventually accepted for funding. The proposals were for studying highway-oriented disciplines of on-going work described above pertaining to vegetation damage, geomorphology and hydrology. Final reports of findings were completed and submitted to Goddard Space Flight Center, Greenbelt, Maryland, under the following titles and contract numbers:

- (1) "DETECTION AND MONITORING VEGETATION DAMAGE ASSOCIATED WITH HIGHWAYS AND HIGHWAY FACILITIES" by E. G. Stoeckeler, R. S. Farrell, and R. G. Woodman, Contract NAS 5-21724, December 1974. 44p.
- (2) "MAP THE DISTRIBUTION OF GLACIOFLUVIAL DEPOSITS AND ASSOCIATED LANDFORMS" by R. G. Woodman, Contract NAS 5-21747, November 1973. 37p.
- (3) "DEVELOP A LAND USE-PEAK RUNOFF CLASSIFICATION SYSTEM FOR HIGHWAY ENGINEERING PURPOSES" by E. G. Stoeckeler, R. S. Farrell and R. G. Woodman, Contract NAS 5-21772, March 1974. 55p.

At about the same time the LANDSAT-1 proposals were sent in, a multidisciplinary proposal was submitted to NASA for investigating SKYLAB photography and imagery. The original intent was to utilize the data collected during the three LANDSAT evaluations for the visual analysis of SKYLAB products. The SKYLAB proposal was accepted after some minor modifications, and the first useable S190A 70mm photography was received January 14, 1974, of the 10 September 1973 and 21 September 1973 orbits. Analysis of these frames commenced with direct stereo viewing, and monocular viewing by projection enlargement using an American Optical Co. GK Model 3689 projector. S190A and S190B photographs of SL/3 and SL/4 orbits were shipped from Johnson Space Center at irregular intervals, usually

received one to several months after the photography was obtained. After the initial evaluation of scenes, additional products were requested and received in the form of 4X enlargements of S190A and 2X enlargements of S190B photography. Analysis and comparisons of spectral bands relative to the detectability of terrain features and events continued, utilizing paper prints and transparencies supplied by NASA and in-house produced prints from NASA black and white negative enlargements.

It is emphasized that in the proposals written for the investigations of imagery and photography for both LANDSAT-1 and SKYLAB programs the prime objective was to explore the visual aspects of the satellite products; to apply photo interpretation methodology for the extraction of data applicable to highway oriented studies by techniques currently in use. The use of sophisticated and expensive enhancement and analysis equipment was considered to be generally beyond the scope of work contemplated within the limiting confines of available funds and time. Equipment readily available at M.D.O.T. facilities was utilized. A multidisciplinary attempt at electronic enhancement analysis of image signatures was attempted for the LANDSAT-1 investigations, with no significant or useful results.

LANDSAT-1 RESULTS

Vegetation Damage Analysis:

Multi-stage study of LANDSAT-1 imagery, U-2 RC-10 photography and larger scale contract underflight photo coverage was accomplished by monocular and projection viewing, stereo viewing of photography and viewing of the image sidelap portion of two LANDSAT scenes imaged on adjacent orbits, in which the stereo effect was attained. Study was made of all remote sensing media available, including color, color infrared and black and white products. In-house produced Diazo transparencies of simulated color infrared were utilized with good results. Many stressed to severely damaged

sites were detected on LANDSAT-1 imagery and referenced to U-2 RC-10 photography. Using ground truth investigations and conventional large scale photography, several sites were documented in detail.

It was concluded that simulated color infrared imagery is the best LANDSAT product for vegetation damage detection. Damage sites as small as three acres were identified on LANDSAT-1 imagery, with 77 percent of all known damage sites in the study area being LANDSAT detected or identified. Surficial water beneath damaged plots aids in the detection of small sites. Coloration changes of foliage due to tree stress or damage are detectable on sites in excess of ten acres. Observable size increases of damage sites were less than anticipated, due to limited repetitive image coverage. The effective monitoring of significant changes on LANDSAT images would require a longer period than the two years covered in the study.

The detection from LANDSAT-1 imagery of very small damage sites generally associated with highways is deemed to be marginal. Larger sites exceeding five acres, and large flowage kills associated with beaver dams, are generally detectable.

Glacial Landforms

Stereoscopic, pseudostereo, monocular and projection analyses were made of LANDSAT-1 imagery for the detection of glacial landforms, in conjunction with highway materials surveys, conventional aerial photography and NASA-acquired U-2 photography utilized as ground truth data. Investigative efforts of data extraction from LANDSAT-1 imagery were made primarily using standard photo interpretation methods and basic available equipment. To acquire the objective information and uses proposed, namely to develop a landform classification system and compile a surficial

geologic map of Maine, it was concluded that for the method employed, the resolution and registration of LANDSAT-1 imagery was not satisfactory. The identification and mapping of small landform units, particularly those for which previous information did not exist, could not be adequately performed to fulfill the original intent of the proposal. General viewing of broad features and previously known formations can be accomplished. Smaller features may occasionally be identified but detail sufficient for detection of new deposits and the development of a classification system by standard interpretation methods is lacking. Some academic considerations as to ice trend directions and large regional relationships of glacial features were noted during the study, but this aspect was not detailed within the scope of the proposal.

Land Use-Peak Runoff (Hydrology):

Standard photo interpretation techniques were used for the study of stereo relief in the sidelap portion of LANDSAT-1 scenes imaged on adjacent concurrent and multiseasonal orbits. The pseudostereo and enhancement effects afforded by viewing the same scene imaged in different bands and different seasons in combination also proved very helpful for increased data extraction. Successive shifts of orbit location over a one year period allowed nearly complete stereo coverage of the State by viewing the overlap portion of adjacent orbital scenes.

LANDSAT-1 imagery obtained 23 April 73 during near peak flooding conditions and 22 July 73 at normal or low water stage within the Penobscot River watershed allowed direct comparison of hydrologic conditions on a timely basis. The ridge line and vegetation types of a select watershed were determined from LANDSAT-1 imagery, aided by repetitive coverage, available U-2 photography, conventional large scale photography and ground truth investigations. Flood data maps and land use maps of the watershed were prepared as potential reference data for future land use-peak runoff studies.

It was concluded that repetitive cloud free LANDSAT passes over a watershed of several square miles, to produce stereo coverage, are necessary for hydrologic and land use studies. Stereo viewing is obviously better than monocular, and color products are a distinct advantage over black and white scenes. More closely spaced orbits, for greater sidelap coverage, would greatly improve data extraction potentials of future satellite imagery.

From these brief summaries of the LANDSAT study results, it can be seen that the value and application of data extracted from very small scale imagery varies according to the discipline being investigated and the amount of detail required. Intuitively, then, it follows that investigations requiring data of a synoptic and kinetic nature will probably achieve greater success than those requiring the input of finite and static information. The availability of multi-seasonal cloud free coverage by many scenes is essential to a study of large areas of varying water storage or snow cover areas, for example, whereas a single scene may be extremely useful for defining bedrock structure. However, the investigator that hopes to delineate one acre gravel pits from LANDSAT imagery will be frustrated.

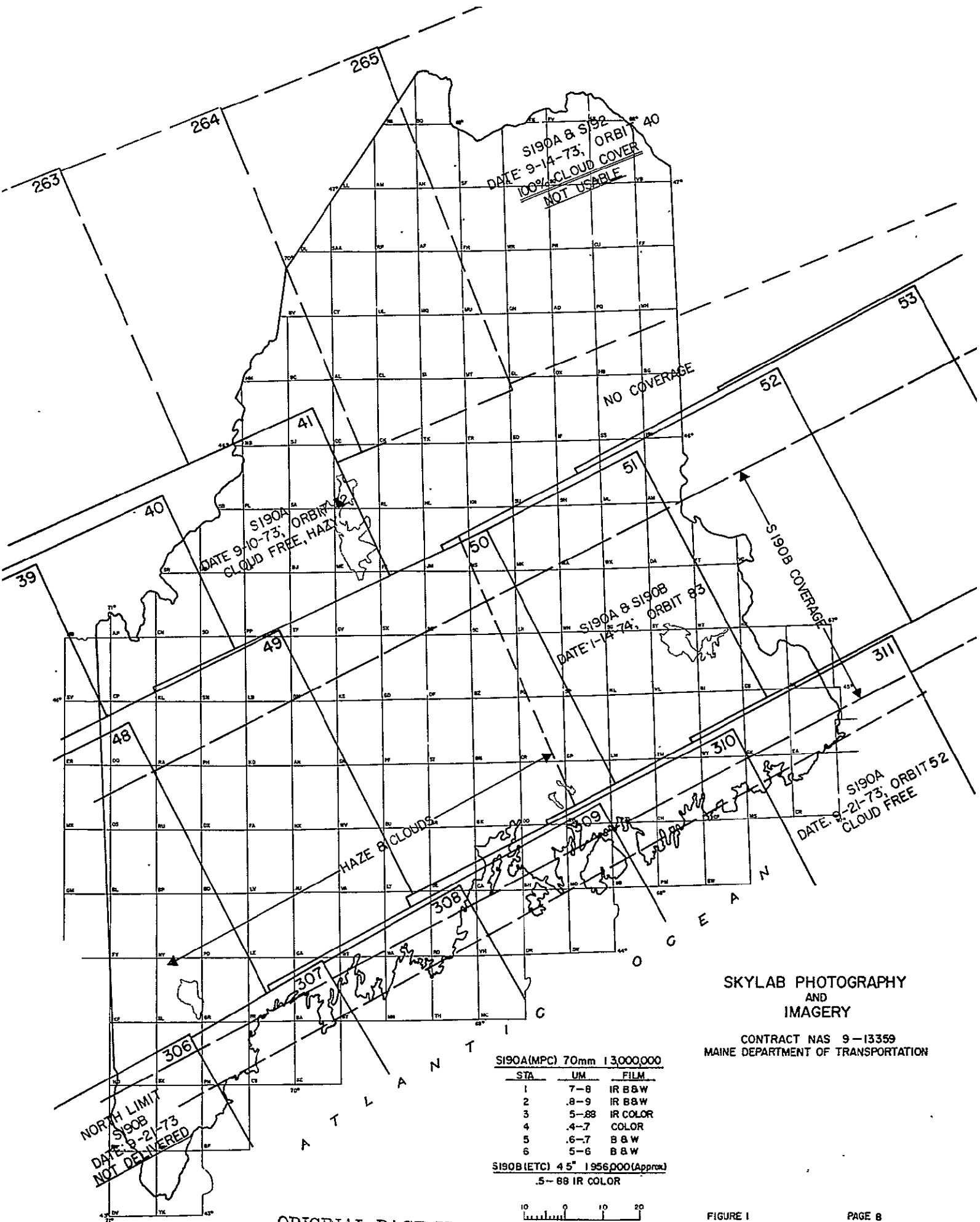
The LANDSAT-1 and SKYLAB proposals were formulated with very little prior knowledge of the type and capabilities of the imagery to be utilized. Had this knowledge been available, the scope and objectives would have been broadened for a more realistic approach to the problems. The usefulness of data obtained from the geomorphology study, for highway utility, was minimal, but potential uses were realized during the study that were not included in the original proposal. Vegetation damage detection proved to be feasible for sites above five acres in extent. Data gained for broad hydrologic studies showed that such investigations can be performed with LANDSAT imagery, given optimum synoptic and repetitive coverage. It is

emphasized that U-2 aircraft photography supplied by NASA for the SKYLAB and LANDSAT-1 investigations was indispensable to the execution of all discipline studies.

As previously stated, the SKYLAB study is, in effect, a continuation of the LANDSAT-1 studies for a multidisciplinary approach, utilizing previously gained remote data and ground truth for comparisons of all remote sensing media. As was expected, the vagaries of Maine weather caused obscuration of the ground by cloud coverage during certain orbits, as was the case with many LANDSAT passes.

Figure 1 shows the actual photograph scenes available for study, imaged during four orbits of SL/3 and SL/4 over the state. It will be noted that SKYLAB S192 imagery was not available for analysis, and very little area of multiseasonal coverage was obtained.

The approach used in evaluating SKYLAB data was basically the same as for LANDSAT-1, although some additional comparisons were made in view of the different type of data format. Comparisons with U.S.G.S. topographic maps were made in addition to comparisons of remote sensing media. Also, some data are described that were not specifically outlined in the original objectives, particularly in the geomorphology section.



SKYLAB PHOTOGRAPHY
AND
IMAGERY

CONTRACT NAS 9-13359
MAINE DEPARTMENT OF TRANSPORTATION

S190A(MPC) 70mm 1:3,000,000

STA	UM	FILM
1	7-8	IR B&W
2	.8-9	IR B&W
3	5-88	IR COLOR
4	.4-7	COLOR
5	.6-7	B & W
6	5-6	B & W

S190B(ETC) 4 5" 1:956,000(Approx)
.5-68 IR COLOR



FIGURE I

ORIGINAL PAGE IS
OF POOR QUALITY

ENVIRONMENTAL QUALITY/ECOLOGY: VEGETATION DAMAGE

BACKGROUND AND INTRODUCTION

Ernest Stoeckeler² initiated a study in 1970 to determine the feasibility of detecting vegetation damage associated with highways and highway facilities employing airphoto interpretation techniques. Highway-associated and other damage can be caused by many factors: soil pollution from salt; ground water modification by culverts, embankments, road cuts, or compaction; ground water modification by impoundment by roadway embankment dams or beaver dams; sun scald, desiccation and wind breakage caused by right of way thinning; air pollution and herbicides; combinations of these and other complex contributing influences.

Several years may be required to produce chlorosis in diseased specimens, a visual symptom that can be observed by remote sensing. The time required for trees to attain toxic levels of salt concentration, or mortality from excessively dry or wet conditions, varies considerably with terrain condition especially the characteristics of drainageways which carry runoff from a highway or storage area source of salt. It would, therefore, be desirable to monitor the entire state to detect and map new damage sites and record changes in known areas.

The objectives of the 1970 pilot study were to determine (1) the suitability of different film types to detect diseased vegetation caused by salt and/or drowning, (2) the time of year when image contrast between diseased and healthy trees is most pronounced on color, color infrared and black and white films, and (3) the most economical scale of photography for the study and monitoring of statewide roadside vegetation damage. Mr. Stoeckeler, in 1972, foresaw that synoptic and recurring imagery and photography

²Soils Research Scientist, Materials and Research Division, Maine D.O.T.

of the State, that would become available through the LANDSAT and SKYLAB vehicles, would be potentially very valuable sources of information for pursuing these study objectives.

Several definite conclusions from the 1970 study can be made with respect to the seasonal aspects, with reference to damaged spruce and fir. These species have a bright green image having a high contrast against the magenta hue of healthy stands in color infrared obtained in late June and early July. These particular species, very common to moist cool habitats in Maine, are susceptible to damage by salt and ground water regime changes, as are some swamp hardwood species.

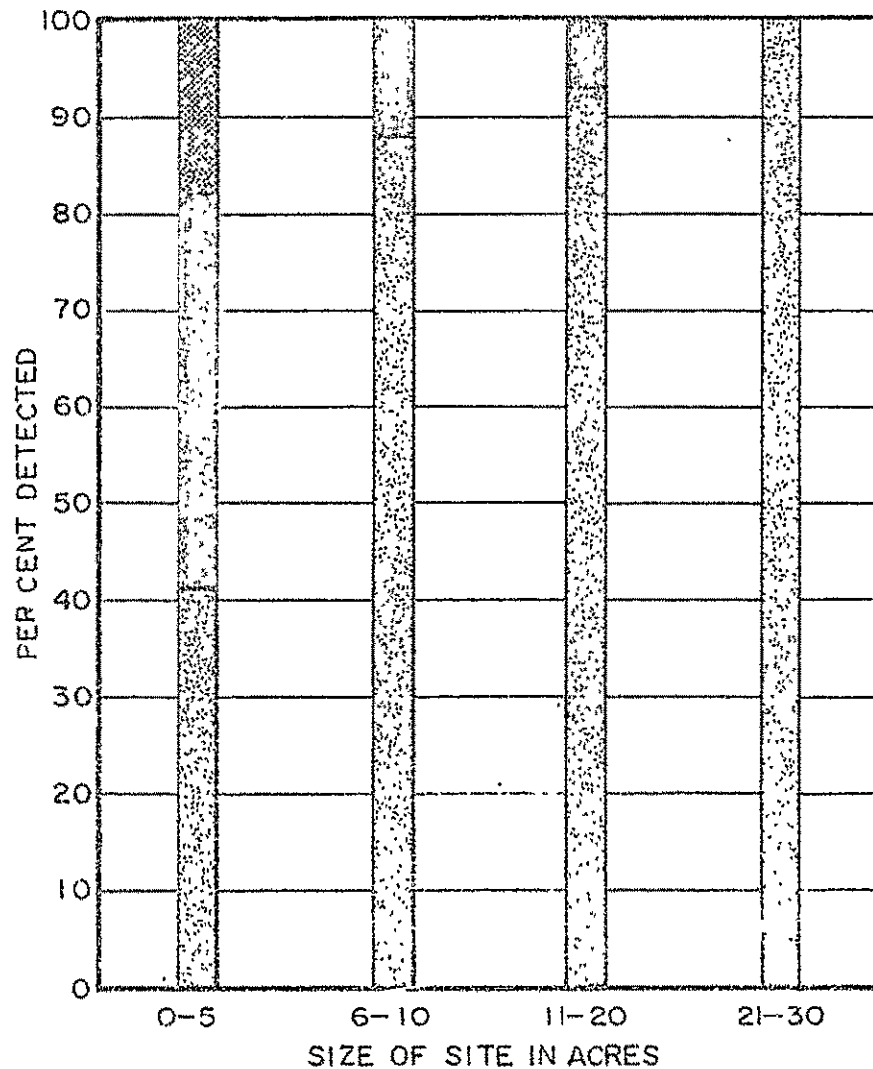
Damaged spruce-fir stands of an acre or more and up to a mile from a salt and sand maintenance lot were located, and recorded on 35mm color infrared film. At a scale of 1:20,000, damaged plots of 1/10 acre can be detected on late June photography. Damage white pine and several varieties of maple can be detected on both color and color infrared film obtained in early summer. However, the color differential and contrast is more subtle than with spruce and fir. It was surmised that contrast enhancement might be achieved through color composite techniques using multispectral band combinations. Several spruce-fir tamarack stands of various sizes were investigated for the original 1970 study. Many of these sites were then utilized as ground truth data for the analysis of LANDSAT-1 imagery (Stoeckeler, Farrell, and Woodman, December, 1974). It was found that stereo models of this imagery were the most sensitive for detection of damage sites. Simulated CIR imagery was superior to any black and white single band imagery, and bands 6 and 7, in the infrared range, were determined to be better than bands 4 and 5. For best identification, multiseasonal imagery is necessary, i.e., 'high water' spring imagery combined sidelap stereo and/or pseudostereo with summer imagery, where smaller damaged sites can be better identified than on single stereo pairs. The increased ability to detect

damaged trees is attributed to the presence of standing water beneath the vegetation canopy, which accentuates the color difference in stereo viewing. Damaged areas as small as about three acres were detected in the LANDSAT study. Correlations of 80 percent correctly identified sites were obtained for damage areas of six acres and larger. Figure 2 contains graphic presentations of the LANDSAT-1 study findings, showing size, distribution of damage sites and media upon which sites were first correctly identified.

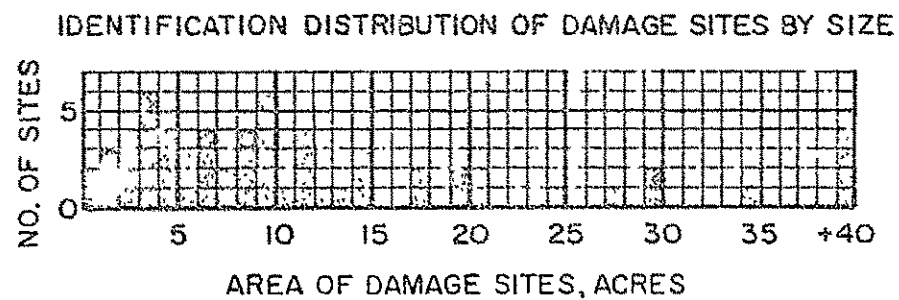
Areas studied for the LANDSAT-1 vegetation report are located in the Penobscot River valley, a region of low stream gradients and swampy terrain. Water courses are, therefore, very sensitive to drainage blockage and resulting vegetation damage from flooding and/or saline contamination. Damaged sites within the study region are generally between four and fifteen acres in extent.




It was initially planned to utilize SKYLAB photo coverage of the LANDSAT-1 study area, which would allow a continuation of investigations and comparisons of vegetation damage sites imaged by the two satellites. However, only one SL/4 mission over this section of Maine occurred, on January 14, 1974, when water bodies were ice covered and about six inches of snow blanketed the ground. Both S190A and S190B photographs from this mission were studied for identification of known damage sites. It was determined that winter imagery of the terrain, in itself, is not adequate for successful damage detection because of the very low contrast.

Since desirable SKYLAB coverage of the LANDSAT-1 study area is not available, photography obtained during SL/3 orbits was analyzed for selection of a suitable alternate region of damage site study. Initial study of the 10 September 1973 photographs of western Maine indicated that the CIR and color frames are extremely dense and therefore too dark for satisfactory



COMPARISON OF SIZE DISTRIBUTION
BY PER CENT AND DETECTION MEDIA
IN THE LANDSAT-1 STUDY AREA



- IDENTIFICATION PROCEDURE
-  IDENTIFIED ON U-2 ONLY
 -  IDENTIFIED ON U-2, THEN ON LANDSAT-1
 -  LANDSAT-IDENTIFIED, U-2, CONFIRMED

DAMAGE, LARGER THAN 20 ACRES
SHOULD BE DETECTABLE ON
APPROPRIATE LANDSAT IMAGERY

Figure 2

location of vegetation damage sites. Color products obtained on the 21 September 1973 orbit over the coastal area of Maine are of considerably better quality with regards to density and contrast, and have a higher potential value for vegetation damage detection. Land coverage of this mission is limited to a relatively narrow band of coastal terrain, but has the advantage of being reasonably close to the home office, to allow economical field checks of any newly detected sites. The study area was ultimately limited to portions of the five-quadrangle region shown in Figure 3. U-2 RC-10 photography obtained on underflight missions for LANDSAT-1 and SKYLAB in late summer of 1972 and 1973 was available for additional 'ground truth' data.

Techniques

Three frames of SL/3 S190A photography obtained during Orbit 52 on 21 September 1973 were utilized for the study. 70mm transparencies and 9" X 9" 4X transparency enlargements of scenes 309, 310, and 311 that cover the study region were available in the six spectral bands.

A known site of damage, location No. 4 on the Ellsworth Quadrangle, (See Figure 7), was located on the photographs. This site was initially observed in stereo on the four bands of black and white, on color and on color infrared. From the preliminary study it was concluded that the color infrared, black and white infrared and to a degree the color would be useful for the detection of additional damaged sites, corresponding to camera stations 3, 1, 2, and 4 respectively. The known location could not be detected on panchromatic photos, stations 5 and 6. Detection was not achieved on the color product, but wetlands detection was aided by this band.

Each film type of the three frames was studied in stereo transparencies individually. Combinations of film types were then studied in stereo, i.e., camera stations 1 and 2, 2 and 3, etc. until the six combinations had been

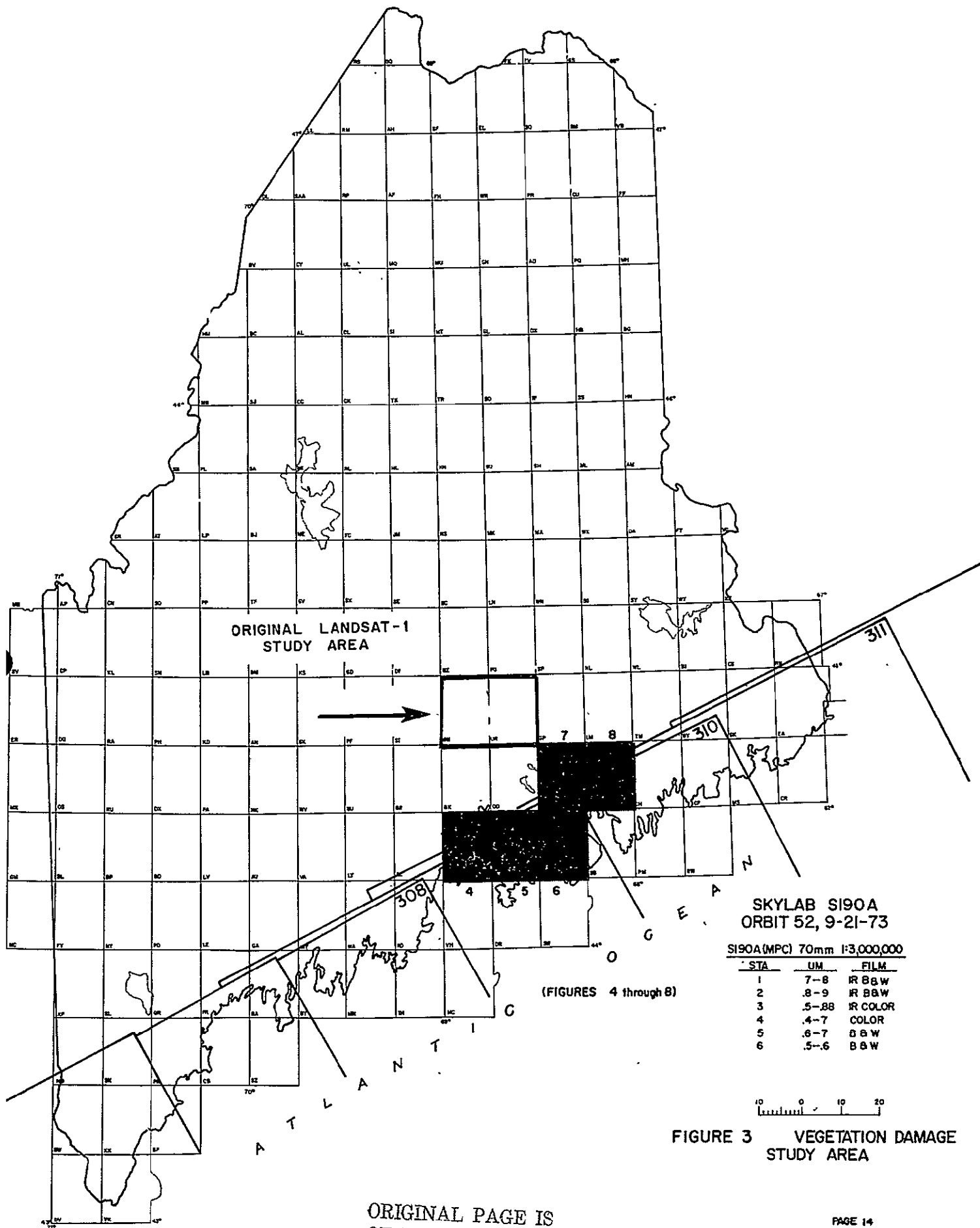


FIGURE 3 VEGETATION DAMAGE STUDY AREA

investigated. Potential sites of damage thus detected were plotted on 1:125,000 scale topographic maps. The area was then studied on NASA U-2 RC-10 (color infrared transparencies) photography obtained 20 August 1972, 20 September 1972 and 13 September 1973. It will be noted that this last coverage was flown only seven days prior to the SKYLAB photography. Sites detected on U-2 products were located by direct overlay of 1:125,000 scale topographic map transparencies.

LANDSAT-1 imagery of the area was also analyzed in conjunction with the SKYLAB photography. The best visual results obtained from LANDSAT data for vegetation damage detection, as mentioned previously, were provided by a combination of early spring 'high water' imagery and simulated color infrared imagery. However, a similar combination of LANDSAT-1 images is not available for comparison with SKYLAB data in the study area due to cloud obscuration of the spring imagery. Therefore, a 1 September 1972 NASA-produced CIR scene and a 10 October 1973 DIAZO CIR scene were used in sidalap stereo and pseudostereo effect combinations. Probable damage sites were plotted on 1:125,000 scale maps.

Results

Figures 4 through 8 are maps of the study area showing the locations and types of detected damage sites, with symbolism indicating the detection procedure. Table 1 lists the sites, size, cause of damage and/or reason the site was identified, and the remote sensing medium or media upon which each site was first identified. Figures 9 and 10 are graphic presentations of Table 1 data that show percentage comparisons of site distribution, site size and identification media. Figure 9 contains LANDSAT-1 and U-2 data; Figure 10 contains SKYLAB, LANDSAT-1 and U-2 data compiled for the study area.








Seventy-eight sites are listed, of which seven were found to be errors

of identification on SKYLAB. Six errors were mis-identification of dark-toned softwood stands in low terrain having spectral signatures and tonal qualities that closely resemble some areas of tree damage. A single mis-identified site in higher terrain, location No. 2 in the Blue Hill quadrangle (Figure 5), is possibly a flaw on the S190A CIR, as the signature was not located on LANDSAT-1 imagery or U-2 photography.

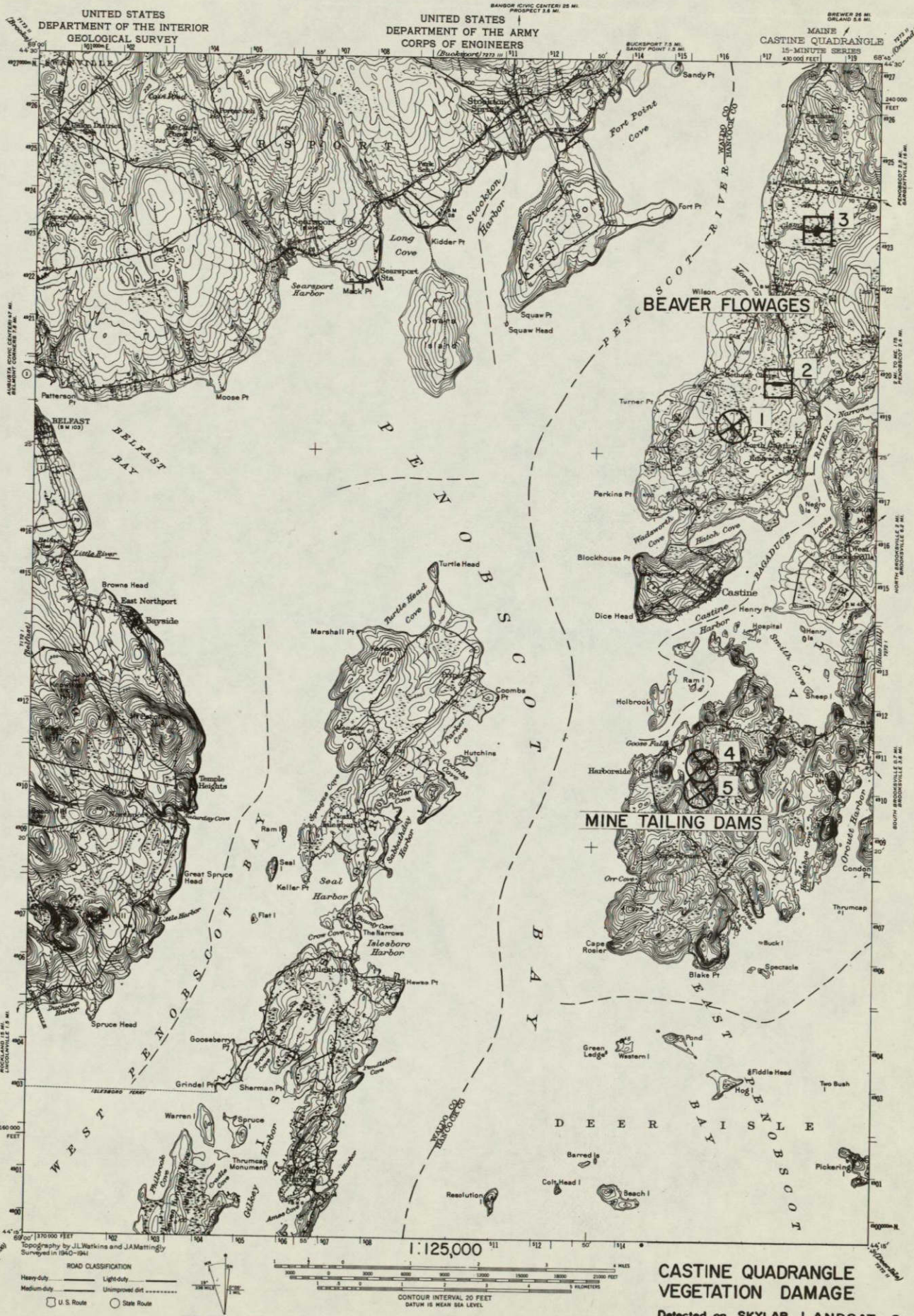
SKYLAB
VEGETATION DAMAGE STUDY

FIGURES. 4 THROUGH 8

EXPLANATION

-  SKYLAB Detected Damage, U-2 Confirmed
-  SKYLAB Detected, Non-Damage Site
-  SKYLAB and LANDSAT-1 Detected, U-2 Confirmed
-  LANDSAT-1 Detected, U-2 Confirmed: Located on SKYLAB
-  LANDSAT-1 Detected, U-2 Confirmed: Not Located on SKYLAB
-  U-2 Detected, Located on LANDSAT
-  U-2 Detected Only

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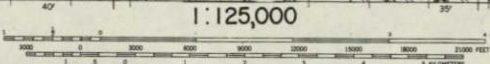


CASTINE QUADRANGLE
VEGETATION DAMAGE
Detected on SKYLAB, LANDSAT 8
U-2 RC-10 Imagery
FIGURE 4 PAGE 17

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Maped, edited, and published by the Geological Survey
Control by USGS and USCGS
Topography by plane-table surveys 1941
Revised 1957
Hydrography compiled from USCGS charts 307 (1956),
308 (1956), 309 (1954), and 1203 (1955)
Polyconic projection. 1927 North American datum
30,000-foot grid based on Maine coordinate system,
east zone
(2000-meter Universal Transverse Mercator grid ticks,
zone 19, shown in blue)

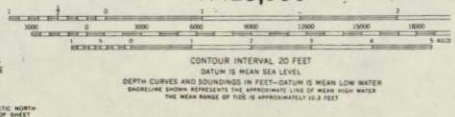


CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET-DATUM IS MEAN LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 10.2 FEET
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, WASHINGTON 25, D. C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

**BLUE HILL QUADRANGLE
VEGETATION DAMAGE**
Detected on SKYLAB, LANDSAT &
U-2 RC-10 Imagery
FIGURE 5 PAGE 18

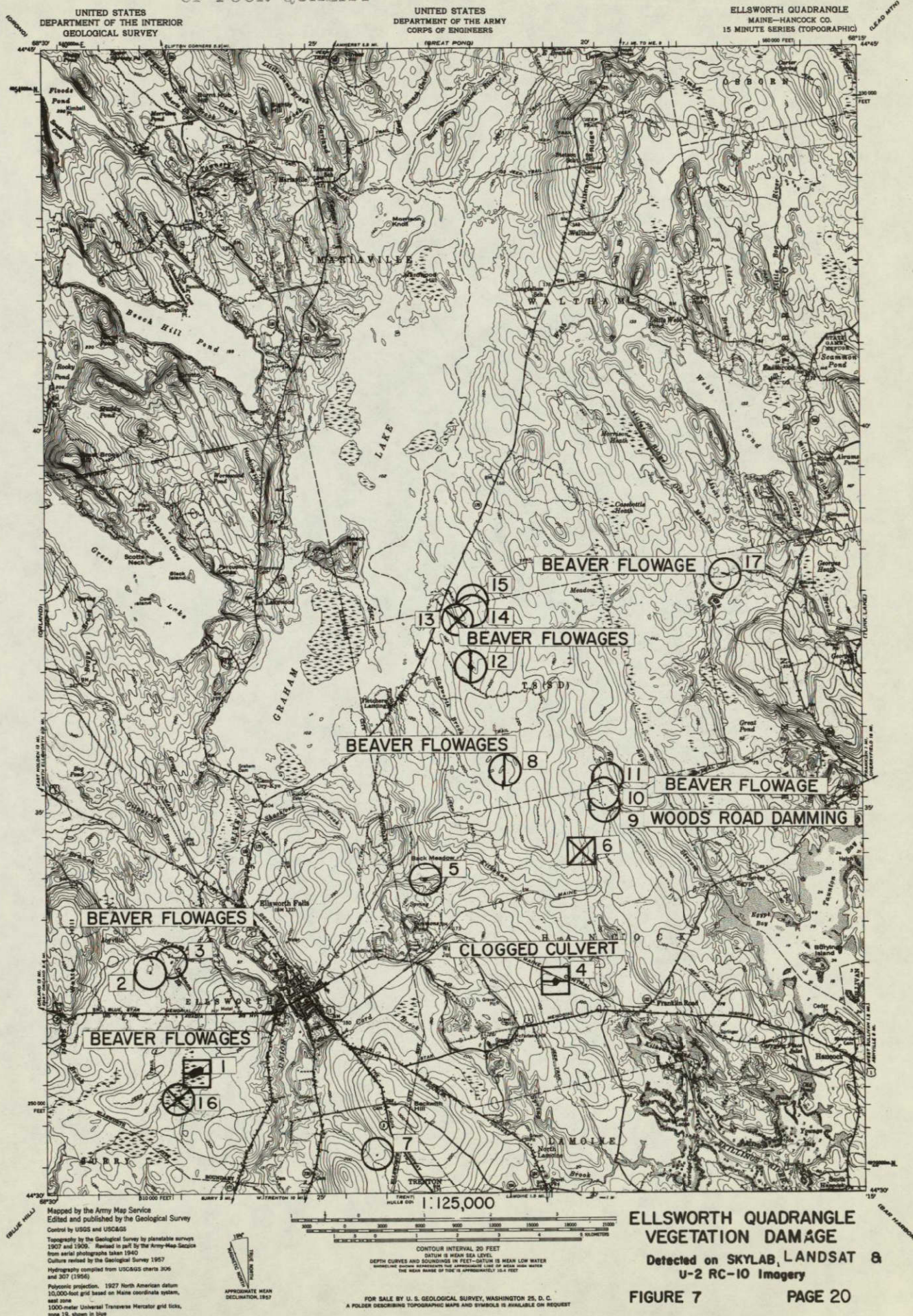


Mapped, edited, and published by the Geological Survey
Control by USGS and USC&GS
Topography by planetable surveys 1934, 1935, 1939, and 1940
Revised 1956
Hydrography compiled from USCGS charts 306 (1954), 307 (1956),
and supplementary information
Polyconic projection. 1927 North American datum
10,000-foot grid based on Maine coordinate system, east zone
1000-meter Universal Transverse Mercator grid ticks,
zone 19, shown in blue



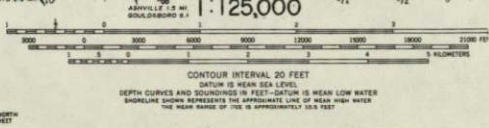
**MOUNT DESERT QUADRANGLE
VEGETATION DAMAGE**
Detected on SKYLAB, LANDSAT &
U-2 RC-10 Imagery

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Mapped, edited, and published by the Geological Survey
Control by USGS and USCGS
Topography by photostatic survey 1953. Revised 1957
Hydrography compiled from USCGS charts 306 and 1202 (1956)
Polyconic projection. 1927 North American datum
13,000-foot grid based on Maine coordinate system, and zone
1000-meter Universal Transverse Mercator grid ticks,
zone 18, shown in blue



**TUNK LAKE QUADRANGLE
VEGETATION DAMAGE**

Detected on SKYLAB, LANDSAT &
U-2 RC-10 Imagery

TABLE I

(PAGES 23 THROUGH 27)

TABULATION OF 78 EVENTS DETECTED ON SKYLAB S190A PHOTOGRAPHY, LANDSAT-1 IMAGERY AND U-2 RC-10 PHOTOGRAPHY IN THE FIVE-QUADRANGLE STUDY AREA. THE MAJORITY OF SITES DETECTED ARE AREAS OF DEAD AND/OR STRESSED TREES ASSOCIATED WITH BEAVER DAM FLOODING. TEN SITES WERE IDENTIFIED ON SKYLAB AND CONFIRMED AS DAMAGE ON U-2 PHOTOGRAPHY. SEVEN SITES FIRST DETECTED ON SKYLAB WERE FOUND TO BE NON-DAMAGE AREAS. THREE SITES WERE LOCATED ON SKYLAB PHOTOGRAPHY AFTER BEING IDENTIFIED ON U-2 AND LANDSAT IMAGERY. EIGHT SITES DETECTED ON LANDSAT AND CONFIRMED ON U-2 COULD NOT BE IDENTIFIED ON SKYLAB S190A PHOTOGRAPHS. THE REMAINDER ARE LANDSAT-1 AND U-2 IDENTIFIED SITES ONLY.

U.S.G.S. 15-MIN. QUADRANGLE	SITE	APPROX. SIZE ACRES	CAUSE OF DAMAGE OR DETECTION	DETECTION/IDENTIFICATION MEDIUM							REMARKS				
				SKYLAB S190A SEPT. 21, 1973			LANDSAT CIR		U-2 RC 10 CIR						
				COMBINATIONS CAMERA STA.			STEREO								
				1/1	1/2	1/3	2/2	2/3							
<u>CASTINE</u> (Figure 4)	1	6	Beaver Dam		6				X	X	Softwood; appears as pond on 1/1 & 1.				
	2	28	Beaver Dam	X	X	X	X	X	X	X	Hardwood; partial meadow flooding				
	3	10	Beaver Dam			X		X	X	X	Softwood swamp				
	4	4	Damming by Mine Waste						X	X	Hardwood				
	5	5	Damming by Mine Waste						X	X	Hardwood				
<u>BLUE HILL</u> (Figure 5)	1	21	Beaver Dam			X		X	X	X	Swamp Softwood. SKYLAB detection aided by IR B&W				
	2	(Error)	Cut Area					X			Hill Top				
	3	(Error)	Softwood					X			Abandoned beaver flowage				
	4	4	Beaver Dam							X	Elongate flowage in hardwood				
	5	(Error)	Flooded Bog					X							
	6	1	Beaver Dam							X	Hardwood along drainageway				
	7	10	Damming by Mine Waste						X	X	Upland Mixedwood predominantly hard				
	8	2	Not known						X	X	First U-2 detected located on LANDSAT Swamp brush				
	9	7	Culvert obstruction			X		X	X	X	Mixedwood/Hardwood damage				
	10	0.5	Damming by tote road							X	Cut over mixedwood				
	11	0.5	Damming by tote road							X	Cut over mixedwood				
	12	0.5	Beaver dam							X	Hardwood				
	13	1	Beaver dam							X	50' X 400' Swamp				

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TABLE I

U.S.G.S. 15-MIN. QUADRANGLE	SITE	APPROX. SIZE ACRES	CAUSE OF DAMAGE OR DETECTION	DETECTION/IDENTIFICATION MEDIUM							REMARKS	
				SKYLAB S190A SEPT. 21, 1973 COMBINATIONS CAMERA STA.			LANDSAT CIR STEREO		U-2 RC10 CIR			
				1/1	1/2	1/3	2/2	2/3				
				1/1	2/2	3/3	1/1	2/2				
<u>BLUE HILL</u> (cont.)	14	10	Not known							X	Alder swamp- Detectable on LANDSAT as pond rather than damage	
	15	2	Not known							X	Mixedwood swamp	
	16	<1	Not known							X	Hardwood	
	17	1	Not known							X	Upland hardwood	
	18	<1	Beaver dam							X	Upland hardwood	
	19	<1	Not known							X	Stressed trees	
	20	<1	Beaver dam							X	Stressed trees	
	21	1.5	Beaver dam							X	Stressed and dead trees	
	22	<1	Not known							X	Mixedwood swamp	
	23	2	Not known							X	Stressed hardwood	
	24	4	Beaver dam							X	Stressed hardwood	
	25	6	Flooding			X		X X	X	X	Inundated alder and hardwood swamp adjacent to lake	
	26	(Error)	Swamp			X		X X	X	X	Softwood swamp	
	27	(Error)	Softwood swamp					X			Swamp softwood	
	28	(Error)	Swamp					X			Mixedwood swamp having unusual gray shade. Three very small beaver flowages included.	
	29	14	Not known			X		X X	X	X	Very dark image on IR/CIR combination Part pond and swamp	
	30	<1	Not known							X	Stressed hardwood laag.	
	31	4	Not known						X	X	Upland hardwood & softwood	

TABLE I

U.S.G.S. 15-MIN. QUADRANGLE	SITE	APPROX. SIZE ACRES	CAUSE OF DAMAGE OR DETECTION	DETECTION/IDENTIFICATION MEDIUM							REMARKS	
				SKYLAB S190A SEPT. 21, 1973 COMBINATIONS CAMERA STA.			LANDSAT CIR STEREO 1 SEPT. 72		U-2 RC 10 CIR 1 OCT. 73			
				1	2	3	1	2				
				1	2	3	1	2				
<u>MOUNT DESERT</u> (Figure 6)	1	1	Not known							X		
	2	1	Not known							X	Four closely spaced stressed sites	
<u>ELLSWORTH</u> (Figure 7)	1	14	Beaver dam	X	X	X	X	X	X	X	Ponding of mixedwood swamp. Damage has occurred since 1968	
	2	2.5	Beaver dam							X	Hardwood	
	3	3	Beaver dam							X	Hardwood	
	4	13	R.R. Culvert obstruction	X	X	X	X	X	X	X	Previously known damage site. Large pond in softwood.	
	5	< 1	Not known							X	Dead hardwood	
	6	(Error)	Not known					X			Softwood stand	
	7	< 1	Not known							X	Largely stress	
	8	4	Beaver dam	X			X		X	X	Detected on LANDSAT aided by U-2. Appears as pond on SKYLAB IR	
	9	1	Damming							X	Probable tote road	
	10	3	Beaver dam							X	Three closely spaced flowages	
	11	< 1	Beaver dam							X		
	12	4	Beaver dam						X	X	LANDSAT-detected with aid of U-2	
	13	8	Beaver dam			X		X	X	X	(Extreme photo edge	
	14	1.5	Beaver dam							X		
	15	< 1	Not known							X		
	16	6	Beaver dam						X	X	Standing dead snags in old flowage, drained prior to 1968	
	17	20	Beaver dam	X			X		X	X	Image similar to pond on LANDSAT & SKYLAB IR	

TABLE I

U.S.G.S. 15-MIN. QUADRANGLE	SITE	APPROX SIZE ACRES	CAUSE OF DAMAGE OR DETECTION	DETECTION/IDENTIFICATION MEDIUM							REMARKS	
				SKYLAB S190A SEPT. 21, 1973 COMBINATIONS CAMERA STA.			LANDSAT CIR STEREO 1 SEPT. 72		U-2 RC10 CIR 1 OCT. 73			
				1/1	1/2	1/3	2/2	2/3				
				1/1	2/2	3/3	2/2	3/3				
<u>TUNK LAKE</u> (Figure 8)	1	1	Not known							X		
	2	1	Not known							X		
	3	1	Not known							X		
	4	< 1	Not known							X		
	5	8	Beaver dam		X		X	X	X	X	Swamp softwood and mixedwood	
	6	1.5	Beaver dam							X		
	7	< 1	Not known							X		
	8	< 1	Not known							X		
	9	3	Beaver dam							X	Low brush, alder and softwood	
	10	1	Beaver dam							X	Alder swamp	
	11	4	Beaver dam	X			X			X	Images as pond in hardwood on SKYLAB, but as damage on U-2 CIR	
	12	5	Beaver dam	X			X				Images as pond in hardwood on SKYLAB, but as damage on U-2 CIR	
	13	4	Beaver dam						X	X	LANDSAT-detected with aid of U-2	
	14	< 1	Beaver dam							X		
	15	1.5	Beaver dam							X	Stress on rim of flood area	
	16	3	Not known						X	X		
	17	18	Beaver dam		X		X	X	X	X	50%+ is stress, not kill. SKYLAB- detected, aided by U-2	
	18	3	Beaver dam							X		

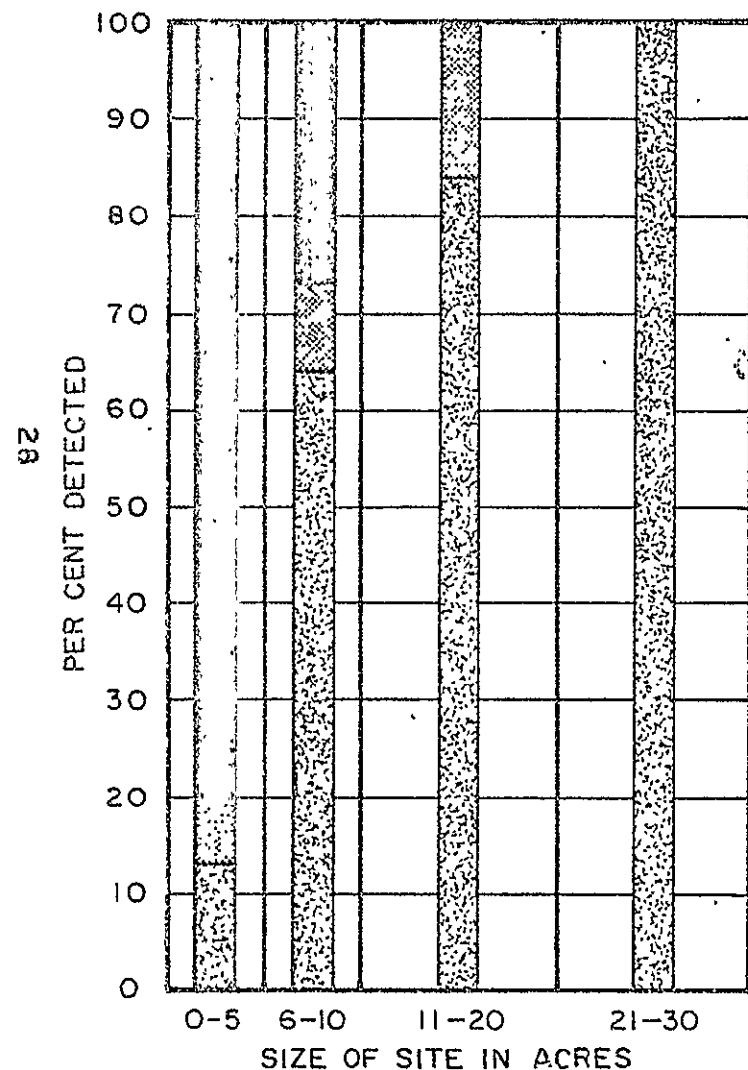
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TABLE I

U.S.G.S. 15-MIN. QUADRANGLE	SITE	APPROX. SIZE ACRES	CAUSE OF DAMAGE OR DETECTION	DETECTION/IDENTIFICATION MEDIUM							REMARKS		
				SKYLAB S190A SEPT. 21, 1973			LANDSAT CIR		U-2, RC10 CIR				
				COMBINATIONS CAMERA STA.								1 SEPT. 72 1 OCT. 73	
				1/1	1/2	1/3	2/2	2/3	3/3				
<u>TUNK LAKE</u> (cont.)	19	12	Beaver dam			X		X		X	X	SKYLAB-detected with aid of U-2	
	20	7	Beaver dam							X	X		
	21	2	Beaver dam								X		
	22	6	Beaver dam								X		
	23	5	Beaver dam							X	X	Old flowage, reverting meadow	

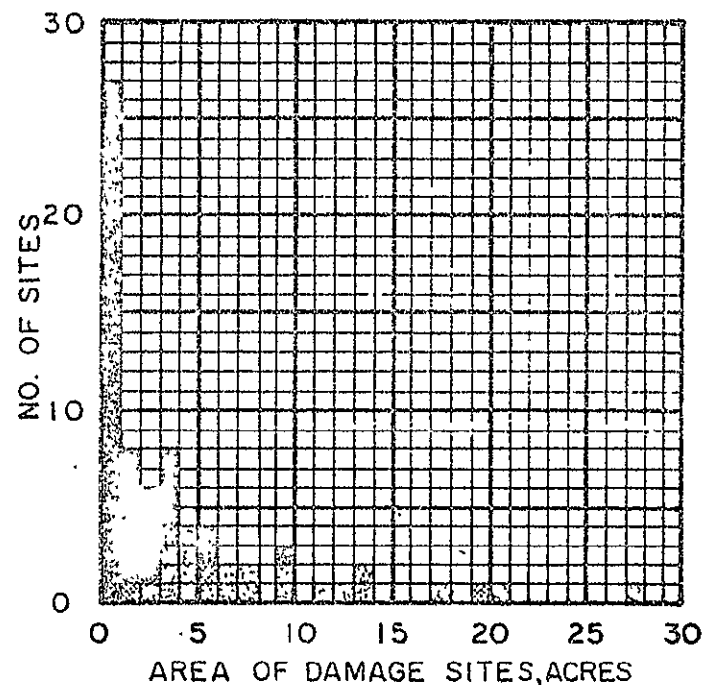
TABLE I

IDENTIFICATION DISTRIBUTION OF DAMAGE SITES BY SIZE



LANDSAT-1

NOTE: Based on the study
of 1 September 72 CIR &
1 October 73 DIAZO
CIR LANDSAT-1 Imagery
of the SKYLAB Study
Area

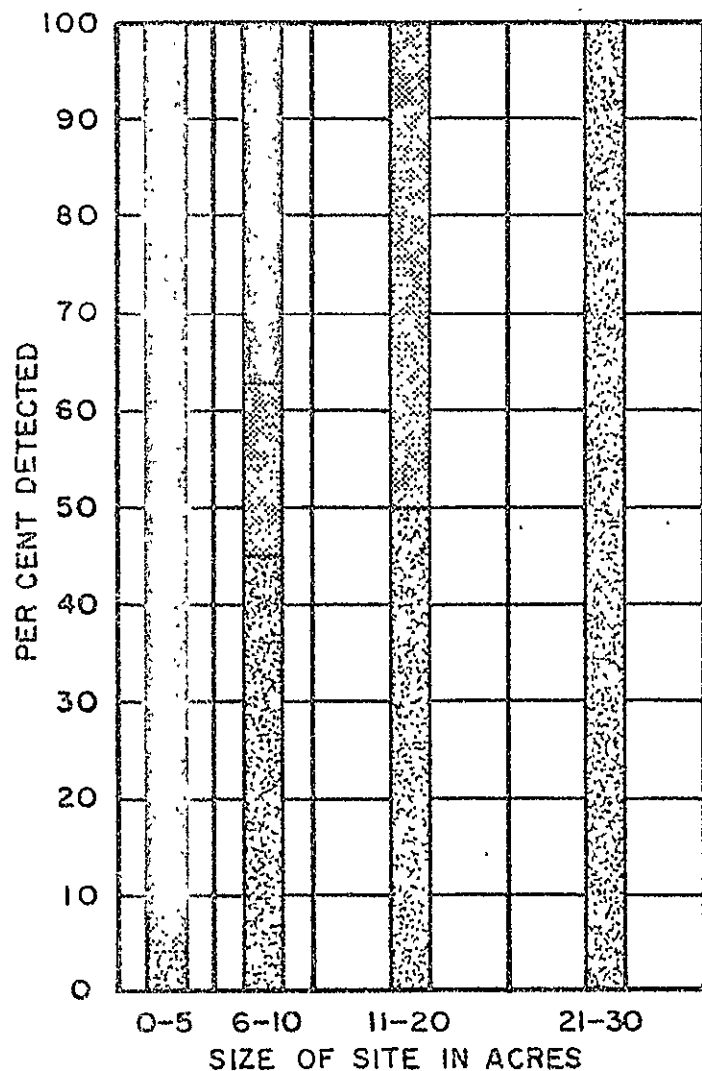


IDENTIFICATION PROCEDURE

- IDENTIFIED ON U-2 ONLY
- IDENTIFIED ON U-2, THEN ON LANDSAT
- LANDSAT IDENTIFIED, U-2 CONFIRMED

DAMAGE LARGER THAN 20 ACRES
SHOULD BE DETECTED ON
APPROPRIATE LANDSAT IMAGERY

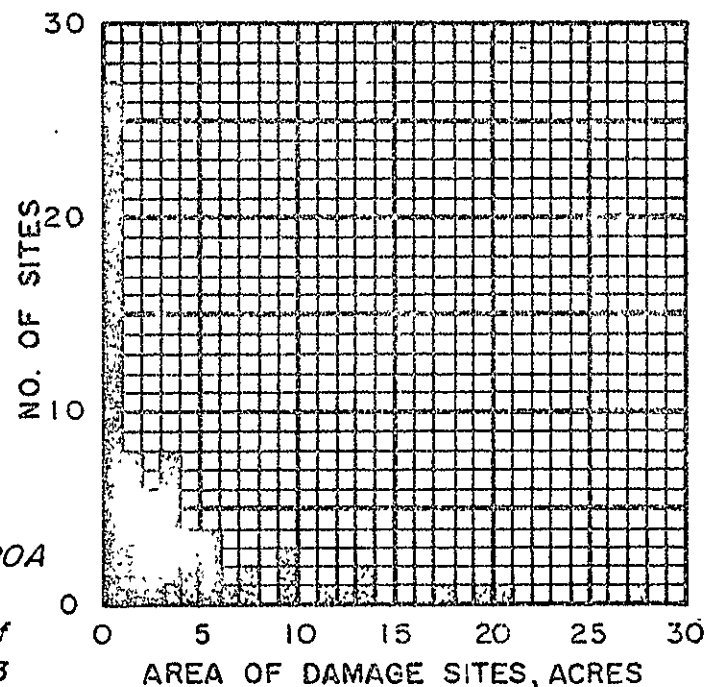
COMPARISON OF SIZE DISTRIBUTION BY PER CENT AND DETECTION MEDIA



SKYLAB

NOTE: Based on the study of 70mm and 9 x 9" SI90A color, CIR, B&W IR & DIAZO Transparencies of Orbit 52, Sept. 21, 1973

IDENTIFICATION DISTRIBUTION OF DAMAGE SITES, BY SI



IDENTIFICATION PROCEDURE

- IDENTIFIED ON U-2 ONLY
- IDENTIFIED ON U-2, THEN ON SKYLAB
- SKYLAB IDENTIFIED, U-2 CONFIRMED

DAMAGE LARGER THEN 20 ACRES
SHOULD BE DETECTABLE ON
APPROPRIATE SKYLAB PHOTOGRAPHY

COMPARISON OF SIZE DISTRIBUTION BY PER CENT AND DETECTION MEDIA

Twenty-four sites, including the seven errors, were detected or identified on SKYLAB S190A photography, for 31% of the total. The smallest site size initially identified on SKYLAB is four acres. Of the seventy-one sites of vegetation damage identified, 45% between six and ten acres and 50% between eleven and twenty acres were ultimately identified or located on SKYLAB. Sites greater than twenty acres in size can be readily identified on SKYLAB photography, but only two in this size range were present in the study region.

Of the seventy-one sites of actual damage seen on all the remote sensing media, twenty-seven, or 38%, are one acre or less in size, fifty-five, or 78%, are five acres or less and sixty-five, or 92%, are ten acres or less.

The analysis of LANDSAT-1 1 September 1972 and 1 October 1973 imagery for this SKYLAB study shows that correct identification of all sites was made as follows: six to ten acres, 64%; eleven to twenty acres, 83%; twenty-one to thirty acres, 100%. Comparable figures obtained for the LANDSAT vegetation damage study (Fig. 2, pg. 12) are: six to ten acres, 88%; and eleven to twenty acres, 93%. It will be noted that the damage site size distribution in the two study areas differ markedly, in that 78% of all known damage sites in this SKYLAB analysis area are smaller than five acres, whereas 29% were smaller than five acres in the original LANDSAT-1 study area (Stoeckeler, et al, 1974). Also, the present SKYLAB study was limited to a one-season analysis because of cloud cover on appropriate comparative LANDSAT-1 imagery, whereas a multi-seasonal approach was possible for the original LANDSAT-1 study.

Discussion and Conclusions

'First look' viewing of SKYLAB S190A film indicated that vegetation damage detection could probably be accomplished by visual means better than

on LANDSAT imagery. Detection and identification has been, surprisingly, less than anticipated, especially for damage sites in the one to ten acre size range. The 70mm chips of color infrared and black and white infrared films appear to have adequate clarity of detail and resolution. However, the B & W IR and CIR 70mm transparency chips and 4X transparencies supplied by NASA and used for visual detection have an inherent graininess that becomes even more pronounced when optically enlarged further by stereo viewing equipment. This granularity limits the observation and detectability of smaller sites, since grains approach the size of damage areas of three to four acres in extent. Reduced contrast results from subtle tonal gradations between the grayish greens, grays, and blacks imaged by damage sites on the CIR transparencies. Sites identified on SKYLAB photography in the four to ten acre size range had standing water beneath the damaged trees, resulting in maximum contrast on infrared films. Therefore, black and white infrared film was better than the CIR film for identifying potential damage at these pond sites, but both films have objectionable graininess. Color infrared may then be referred to for detection of possible tree damage at specific locations.

It was initially planned to monitor by SKYLAB photography the same area studied for the LANDSAT-1 report. The existence of several well-documented highway-associated damage sites here would have allowed comparison opportunities between the two satellite film and image products. However, the only available SKYLAB coverage, hazy winter S190A and S190B photography, was determined to be unsatisfactory and inadequate for proper site identification.

As previously mentioned, the lack of multiseasonal coverage by SKYLAB is considered to be a disadvantage in detecting damage sites, since spring high water coverage scenes could not be checked against 'leaf-on' scenes for

damage confirmation. It was determined during the 1970 study that damaged hardwoods lose their foliage in the fall before healthy trees. One of the LANDSAT scenes used for the present study was imaged 1 October 1973 when partial hardwood fall coloration had occurred. Hardwoods become increasingly lighter in shade during fall coloration when imaged on color infrared film, thereby increasing the contrast with dead or damaged trees in hardwood swamps. This phenomenon probably aided in the detection of some damage sites on LANDSAT imagery.

In the study area used for this report there are no known salt damage sites, and no suspected sites were found. The majority of sites listed are kill areas associated with beaver dams and resulting drowned vegetation where the water areas were detected on SKYLAB S190A photography and damage confirmed on U-2 RC-10 photography. From data obtained for damage associated with beaver flowages, it is apparent that areal extent of damage and damage to individual trees must be extensive before a site can be detected on satellite imagery and photography.

The smallest damage site detected on SKYLAB S190A photography was four acres, as opposed to three acres for LANDSAT imagery. It is estimated by maintenance and field exploration personnel that about 95% of all highway associated damage sites are smaller than two acres. A few older sites, associated with salt storage area runoff into swamps, are larger, in the ten to forty acre size, but these are in the minority. The value of satellite imagery and photography for the detection and monitoring of most highway associated damage, therefore, is limited to the few major sites. This indicates that by the time damage can be detected by satellite it is probable that the major damage has already occurred.

HYDROLOGY

Background and Introduction

For over a decade the Airphoto Interpretation Section of the Maine Department of Transportation has conducted drainage studies using airphoto interpretation techniques. Hydrological information including watershed area, slope, channel characteristics, runoff factors, water storage areas, land use and other salient features is furnished to hydraulics engineers for culvert design purposes. These data have been provided for proposed culvert locations for nearly all new construction and reconstruction highway projects in Maine. Since the mid-fifties thousands of individual watersheds, ranging in size from a few acres to several hundred square miles have been evaluated using photo interpretation techniques with a minimum of field checking.

In Maine it is a standard procedure to acquire both black and white and color aerial photography of a five-mile wide band centered on a proposed construction project about two years prior to actual construction. This photography is used to provide a variety of data for different highway engineering purposes including soils, drainage, materials inventory, right of way and environmental information. These photo interpretation data are used by various departments for planning, location, design, preliminary engineering and actual construction of the roadway.

For drainage studies of watersheds less than 1000 acres in extent, recently flown MDOT photography obtained for five-mile wide bands is adequate for the extraction of current land use data and other dynamic factors which influence runoff rates, and other criteria vital for culvert design purposes. For larger watersheds extending outside of the five-mile wide band covered by recent photography it is often necessary to use coverage which may be

10 to 20 years old. This photography is not always suitable for acquiring accurate land use information.

A land use parameter is currently used in the preparation of MDOT drainage studies, applicable to drainage areas of 1000 acres and smaller. This land use and slope factor (LF) is a judgment factor determined from aerial photographic coverage of the area of interest by experienced photo interpreters, and is included in the data supplied to design engineers for use in the Bureau of Public Roads 1021 Series formula for the determination of peak rates of runoff. The LF factor is based upon the vegetation characteristics within the basin of interest, as seen on reasonably timely airphoto coverage, and the general slope of the major water-course, as estimated from airphoto inspection or as determined from a topographic map. For example, a watershed having mostly forest cover and a slope of less than 2 percent would rate an LF of 0.2. Conversely, pastureland combined with fairly steep slope would be assigned a higher LF of about 0.6. An extreme example would be a small steep watershed in which a large percentage of area is occupied by bare soil, ledge outcrop and/or pavement, which would justify the maximum LF of 1.2. The interpreter's judgement and acuity plays an important role in weighing the significance of variables of vegetation, slope, soil type and storage areas within a watershed relative to their size and location.

The effect of land use apparently decreases as the size of the watershed increases beyond 1000 acres, although major progressive changes over a period of years, such as large clear cut woods operations, may ultimately have an effect on watersheds of several square miles. Current research within the State of Maine and several other locales is aimed towards gathering data for a better understanding of the interaction of land use and hydrographic

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properties. The long range study of repetitive and synoptic LANDSAT-1 imagery and SKYLAB photography will eventually provide valuable information toward this end.

Past design methods have not always proved effective. Land use changes within some watersheds have resulted in the need for larger culverts. Conversely, current methods sometimes result in over-design of drainage structures.

This current study of SKYLAB and LANDSAT-1 imagery for land use data should be viewed, in part, as a means of evaluating which spectral band may give land use information most adaptable to continuing hydrologic research. It is not expected that SKYLAB will solve runoff problems, but may add one or more parameters for a better understanding towards predicting peak runoff. In the present state of design the relationship between land cover/peak runoff and concentration of runoff is understood in a vague way. It is apparent that a watershed containing predominantly farmland will have a shorter concentration time than a forested watershed. The area of farmland or forest needed to produce a significant change in runoff is not at present understood and may be related only in a minor way. Benson (1962) points out that in Maine almost all annual peak discharges occur during the three month period of March through May. Annual peaks are characteristically caused by spring rain, augmented by snow melt, and the peak discharge is progressively increased by snow melt the further north the basin is located. He also states: "Either the three month runoff rainfall ratio or the mean annual temperature for January can be used as an index on the combined effect of accumulated snow and the frozen ground conditions." This relationship of frozen ground, snow melt and heavy spring rains was demonstrated in the LANDSAT-1 study for flooding along the Penobscot River. The relationship suggests that land-use factors may be of minimum importance in Maine in

predicting maximum runoff from large watersheds. The ground in Maine is usually frozen from mid-December to April or May. During this time, precipitation accumulates on the surface as snow. Rain may be absorbed by the snow to increase its water equivalent. If the ground is bare, rain will run off directly, without being absorbed into the ground. In the spring when heavy melts occur, most drainageways are filled to capacity. Any additional rain falls on snow or saturated ground and flood proportional to the rainfall will occur. Indications are that peak runoff may best be predicted when the entire watershed is frozen and considered as impermeable soil, and the only inhibiting factors are swamp storage areas, and, to a degree, softwood stands.

The United States Department of Agriculture (1968) indicates from their research that much reliance is placed on "CN" or curve numbers in determining direct runoff, 'Q'. The CN factor is determined by hydrologic conditions, surficial geology, infiltration rate of the soil and the type of land use. A high CN indicates a short lag time of concentration and retarding of flow. TABLE II, adapted from the USDA publication, shows typical CN values for varying conditions. It is included to illustrate parameters of vegetation and land use relationships for drainage studies similar to more generalized MDOT factors currently in use.

Within the limitations outlined above, a number of land use/cover type schemes were studied. All schemes available for comparison were considered to be too detailed for hydrologic classification as applied to highway studies in Maine. Also, in all of the schemes, elaborate explanations for the various categories were required, which cause some confusion. The Maine State Planning Office (1974) in their classification system has rather obscure distinctions between various classifications, as might be applied to MDOT drainage studies. Categories such as wood stands, abandoned fields, and

TABLE II -- Runoff Curve Numbers (CN) for Hydrologic Soil-Cover Complexes, Derived from Gauged Streams.¹

Land use and treatment or practice	Hydrologic* condition	Hydrologic soil group			
		A	B	C	D
Fallow					
Straight row	----	77	86	91	94
Row crops					
Straight row	Poor	72	81	88	91
Straight row	Good	67	78	85	89
Contoured.	Poor	70	79	84	88
Contoured.	Good	65	75	82	86
Contoured and terraced	Poor	66	74	80	82
Contoured and terraced	Good	62	71	78	81
Small grain					
Straight row	Poor	65	76	84	88
Straight row	Good	63	75	83	87
Contoured.	Poor	63	74	82	85
Contoured.	Good	61	73	81	84
Contoured and terraced	Poor	61	72	79	82
Contoured and terraced	Good	59	70	78	81
Close-seeded legumes or rotation meadow					
Straight row	Poor	66	77	85	89
Straight row	Good	58	72	81	85
Contoured.	Poor	64	75	83	85
Contoured.	Good	55	69	78	83
Contoured and terraced	Poor	63	73	80	83
Contoured and terraced	Good	51	67	76	80
Pasture or range					
No mechanical treatment.	Poor	68	79	86	89
No mechanical treatment.	Fair	49	69	79	84
No mechanical treatment.	Good	39	61	74	80
Contoured.	Poor	47	67	81	88
Contoured.	Fair	25	59	75	83
Contoured.	Good	6	35	70	79
Meadow	Good	30	58	71	78
Woods.	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	25	55	70	77
Farmsteads	----	59	74	82	86
Roads, including Rights of Ways					
Dirt	----	72	82	87	89
Hard surface	----	74	84	90	92

*Hydrologic Condition:

Poor - Rapid Runoff, i.e., saturated, frozen or clay soil
Fair - Moderate Runoff, i.e., partially thawed or till soil
Good - Slow Runoff, i.e., thawed or granular soil

Infiltration Rate:

A - High B - Moderate C-Slow D - Very Slow

¹Adapted from "A Method for Estimating Volume and Rate of Runoff in Small Watersheds" by K. M. Kent, SCS-TP-149, January 1968.

agricultural land can easily be confused, for drainage considerations. It was decided that for hydrologic purposes a simplified vegetation cover type classification system could be used that would encompass current and projected land use information requirements. The classifications, as developed, differ slightly from those used for the LANDSAT study. They are self-explanatory, describe some effect of runoff capacity of the land and are categories applicable to both satellite and low altitude photography. The system devised is shown in Table III, and also as "Explanation" for the comparison illustrations of Tunk Stream Watershed (Figures 12 through 16, 18, and 20).

The simplified basic letter symbols are well suited to the generalized categories necessary for determining runoff characteristics within a given watershed. Number symbols requiring long descriptions are avoided. The symbols are designed to include all aspects of cover, and may be used only where applicable. For example, there is no urban built up area in the Tunk Stream watershed, and snow cover applies only to the S190B imagery study. Snow covered units are often not identified, but are usually fields, barren areas or sparsely wooded areas.

The tentative objectives of the hydrologic study from SKYLAB photography, as set forth in the original proposal, were (a) to develop a land use classification system tailored to runoff characteristics associated with peak flow criteria, (b) to delineate water storage areas, (c) to monitor high water levels during spring breakup periods and different climatic subdivisions of the state, and (d) to prepare maps for flood damage assessment purposes. In addition, attempts were to be made to delineate watershed ridge lines using stereoscopic procedures. Area determinations were to be made and the results compared with areas derived from other media, namely topographic map, U-2 photography, LANDSAT-1 imagery, other SKYLAB bands and conventional aerial photography. Snow cover was to be monitored throughout the winter and spring breakup, if possible.

TABLE III - VEGETATION COVER TYPES FOR HYDROLOGIC MAPPING APPLICATIONS,
DETECTABLE ON SKYLAB AND LARGE SCALE PHOTOGRAPHY.

FOREST

- S - Softwood
- S₁ - Softwood, Cut-Over
- M - Mixedwood
- H - Hardwood
- H₁ - Hardwood, Cut-Over

NON-FOREST

- V_s - Sparse Vegetation
- F - Field and Pasture
- B - Barren Ground (Plowed field,
Pit, Excavation,
Exposed Bedrock)
- U - Urban Built-up

Roads and Rights of Way are indicated.

WATER STORAGE

- Ht - Heath Swamp (Sedge and Low Bush)
- Ss - Softwood Swamp
- Hs - Hardwood Swamp
- Sc - Snow Cover, where applicable

Open Water indicated by shading.

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All data, including flooding observations and land use data for individual watersheds, were to be correlated in an effort to determine the relative importance of interacting influences contributing to peak runoff.

As the SKYLAB coverage progressed (Figure 1, page 8) it became evident that the objectives would have to be modified to fit the available photography. Water storage and land use cover type classifications were combined to a vegetation cover types classification. Mapping of flood areas was not achieved, as no flooding was imaged by SKYLAB, and no monitoring of snow cover was possible, since no repetitive winter or spring photography was obtained.

Techniques

Stereoscopic viewing of all spectral bands of SKYLAB photographic products was the primary means of study, using original 70mm chips, and 2X and 4X transparent enlargements furnished by NASA Johnson Space Center. Since the scales of photos were too small for final mapping purposes, they were enlarged by projection to the common base map scale of 1:125,000. Scale adjustments were accomplished with a 70mm projector and a movable rear projection glass screen, whereby tracings could be made on semi-transparent plastic drafting film. Interpretation of land use/vegetation types cannot be done solely by monocular viewing, and frequent reference to stereo models was made simultaneously with the tracing procedure.

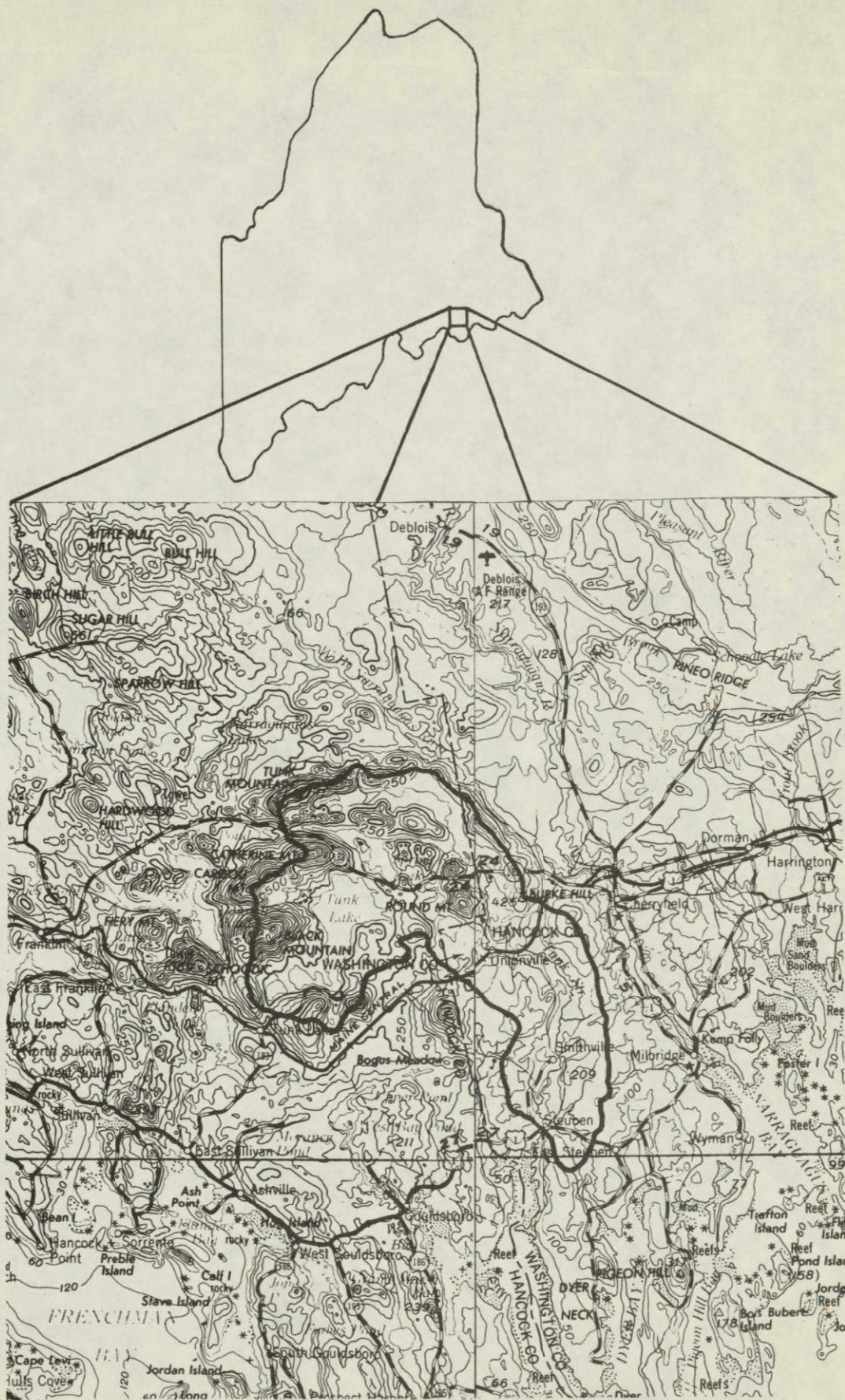
U-2 RC-10 photography was the principal ground truth source. Coverage of the selected watershed was available from underflight missions flown 20 August 1972, 20 September 1972 and 24 March 1973. To remove as much bias in interpretation as possible from the study of the watershed area, all SKYLAB and LANDSAT-1 imagery was analyzed prior to the study of the RC-10 ground truth photos. S190A coverage obtained 21 September 1972 and 14 January 1974 of the

watershed was analyzed, as was S190B coverage obtained 14 January 1974 of most of the watershed.

Several suitable LANDSAT-1 scenes were available for comparison study. The dates of imagery considered most useful in sidelay stereo combination were CIR simulated scenes of 1 September 1972, ID 1040-14482 and 1 October 1973, ID 1435-14473, having fall foliage coloration. The same projection techniques were employed to enlarge this imagery.

The selection of the Tunk Stream watershed study area, Figure 11, page 42, was eventually accomplished after all considerations were given to location, available SKYLAB coverage and other factors. The criteria applied to the selection of vegetation damage sites (pages 11 and 13) were applied here. The watershed is considered large in terms of highway engineering, being 31,100 acres (48.6 square miles) in extent. It is situated in the coastal region and is the largest watershed completely included within SKYLAB S190A photography of the State.

Upon completion of all cover type and ridge line delineations, plotted for each photo media, "goodness of fit" comparisons were made using techniques similar to those described by Erb (1974). An overlay grid having 64 dots/square inch was used. The type maps derived from each media were overlain separately with the ground truth map and grid, and points of agreement and disagreement counted. The total of agreement points divided by the total of all points determined the percent of agreement.



1:250,000

LOCATION OF TUNK STREAM WATERSHED STUDY AREA

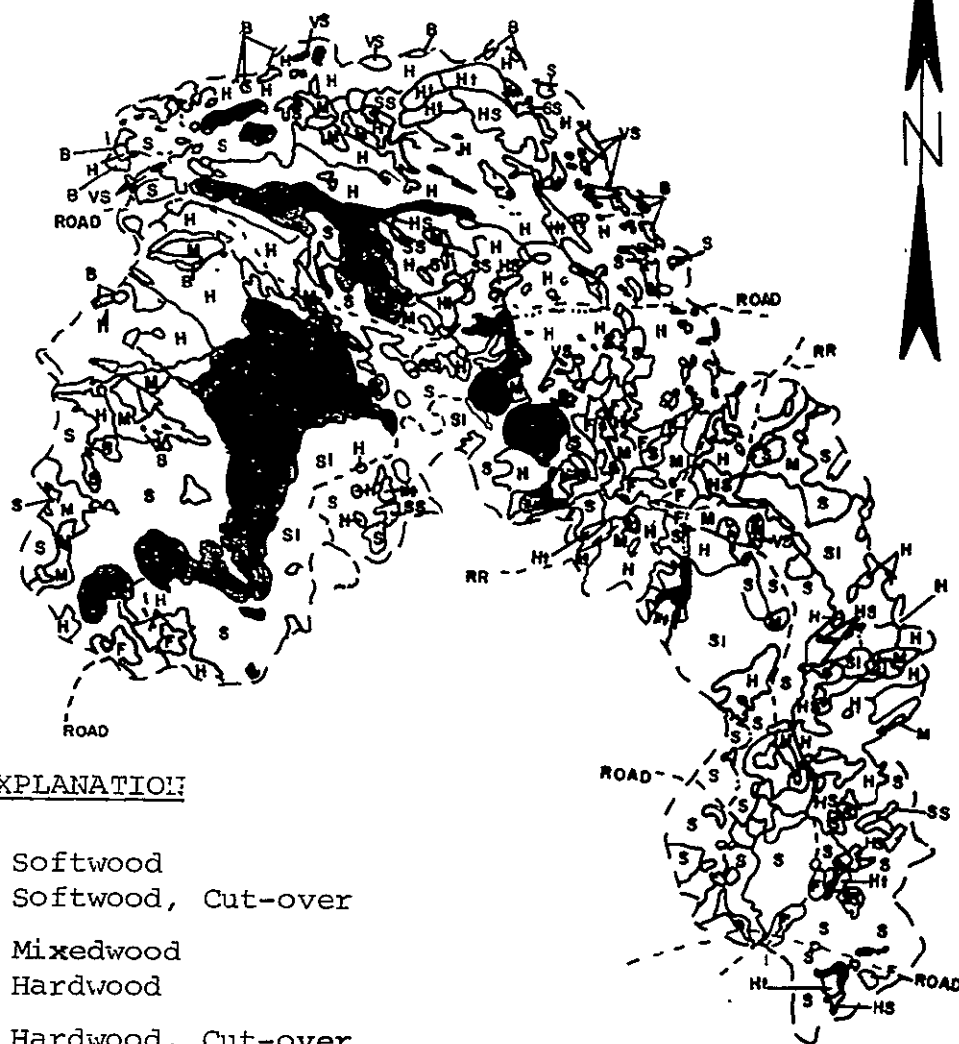
Results

Figure 12 is the composite cover type map generated from the interpretation of U-2 RC-10 (CIR) photography obtained on three different underflight missions. It is the ground truth source reference used as a basis of comparison for the satellite type maps. In the process of checking the SKYLAB maps against this map for unit agreements, the categories of sparse vegetation and barren ground, having very similar signatures, were combined in order that significant dot grid counts might be obtained.

A summary of the goodness of fit of cover types determined for different spectral bands is contained in TABLE IV, page 58, at the end of this section.

Figure 13 is the cover type map developed from the analysis of camera station 1 photography (S190A IR Aerographic B & W, 0.7-0.8 μ m). All major water bodies were readily apparent, and additional water areas associated with heaths were detected. From the stereoscopic study of this band, it was determined that hardwood areas could not be separated from fields, sparse vegetation areas and barren ground, and the attempt to classify the unit was discontinued. About half of the heath was classified as softwood. Agreement of the softwood was 71% and heath areas, 60%.

Figure 14 is the map developed from the analysis of camera station 5 photography (S190A PANATOMIC-X Aerial B & W, 0.6-0.7 μ m). As was expected, cultural features were easily detected, and heaths, sparse vegetation and barren ground could be identified and separated from forest areas. Forest type separation, however, was not achieved and no correlations were attempted. Barren ground/sparse vegetation, field and pasture, rights of ways and heath areas had correlations of 83, 89, 88, and 85 percent respectively.



EXPLANATION

FOREST

- S - Softwood
- S₁ - Softwood, Cut-over
- M - Mixedwood
- H - Hardwood
- H₁ - Hardwood, Cut-over

NON-FOREST

- V_s - Sparse Vegetation
- F - Field and Pasture
- B - Barren Ground (Plowed field, Pit, Excavation, Exposed Bedrock)

WATER STORAGE

- Ht - Heath Swamp (Sedge and low Bush)
- Ss - Softwood Swamp
- Hs - Hardwood Swamp

Scale 1:125,000

TUNK STREAM WATERSHED VEGETATION COVER TYPES

Determined From

U-2 RC-10 COLOR INFRARED, 24 MARCH 73

20 AUG 72

20 SEPT 72

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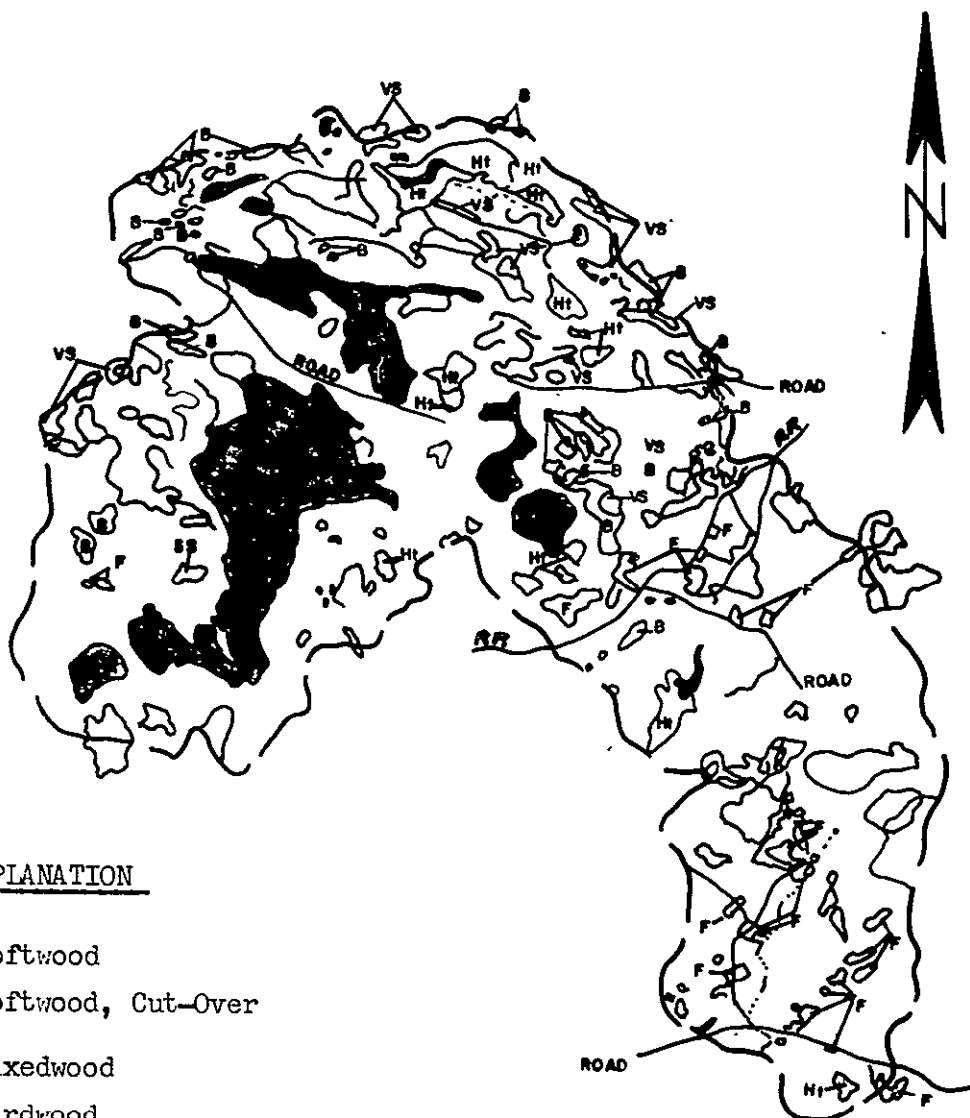
<u>EXPLANATION</u>	
<u>FOREST</u>	
S	- Softwood
S ₁	- Softwood, Cut-Over
M	- Mixedwood
H	- Hardwood
H ₁	- Hardwood, Cut-Over
<u>NON-FOREST</u>	
V _s	- Sparse Vegetation
F	- Field and Pasture
B	- Barren Ground (Plowed field, Pit, Excavation, Exposed Bedrock)
<u>WATER STORAGE</u>	
Ht	- Heath Swamp (Sedge and Low Bush)
Ss	- Softwood Swamp
Hs	- Hardwood Swamp

Scale 1:125,000

TUNK STREAM WATERSHED VEGETATION COVER TYPES

Determined From

SI90A B.&W INFRARED, 21 SEPTEMBER 73



Scale 1:125,000

TUNK STREAM WATERSHED VEGETATION COVER TYPES

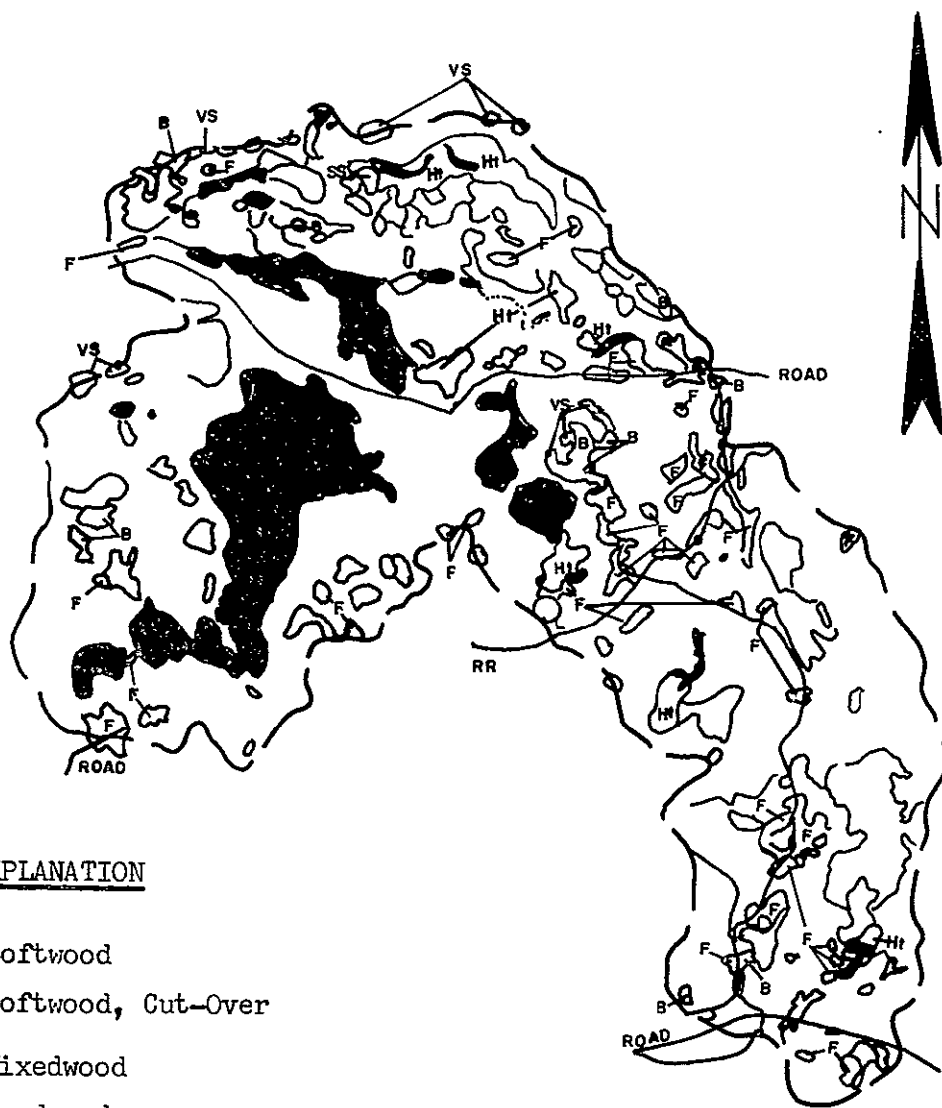
Determined From

SI90A PAN-X, 0.6-0.7 μ m, 21 SEPTEMBER 73

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Figure 15 is the cover type map based on the interpretation of camera station 4 photography (Aerial Color high-resolution, type S0356, 0.4-0.7 μ m). It was anticipated that better interpretation of features might be accomplished with this film than with the station 5 photography, possibly due to the increased shades and tonal differences. However, about the same level of detection and correlation was achieved. Swamp softwood areas, originally thought to be well identified, had about 20% agreement. Water bodies agreed well with the ground truth, but always imaged as slightly smaller. This is probably attributable to the visibility of soil through shallow water around the edges of the lakes.

Figure 16 is the cover type map derived from the analysis of camera station 3 photography (Aerochrome IR color, 0.5-0.88 μ m). It was expected that general cover type classifications could be accurately identified through stereoscopic study of this film, based on previous study of U-2 RC-10 and Vinten CIR photography. The wooded, field, pasture and heath types correlated very well, registering 81 to 90% agreement with ground truth data. Barren ground and sparse vegetation areas registered 76 and 56 percent agreement respectively. The very poor agreement of swamp hardwood, 20 percent, and swamp softwood, 12 percent, is attributable to the extreme grainy characteristic of the film. The graininess causes very indistinct boundaries to be registered between vegetation types, and between types and geomorphic features. Boundaries between high contrast categories such as water (black) and softwood (magenta) are discerned with some difficulty, and categories with similar signatures such as hardwood forest and hardwood swamp are nearly impossible to plot with accuracy. Figure 17 is a 24X enlargement of S190A scene 310 imaged 9/21/73, illustrating this film characteristic. Features indicated on the overlay to this photograph should be compared to those in the overlay for the S190B CIR scene (Figure 19). All major water



EXPLANATION

FOREST

- S - Softwood
- S₁ - Softwood, Cut-Over
- M - Mixedwood
- H - Hardwood
- H₁ - Hardwood, Cut-Over

NON-FOREST

- V_s - Sparse Vegetation
- F - Field and Pasture
- B - Barren Ground (Plowed field, Pit, Excavation Exposed Bedrock)

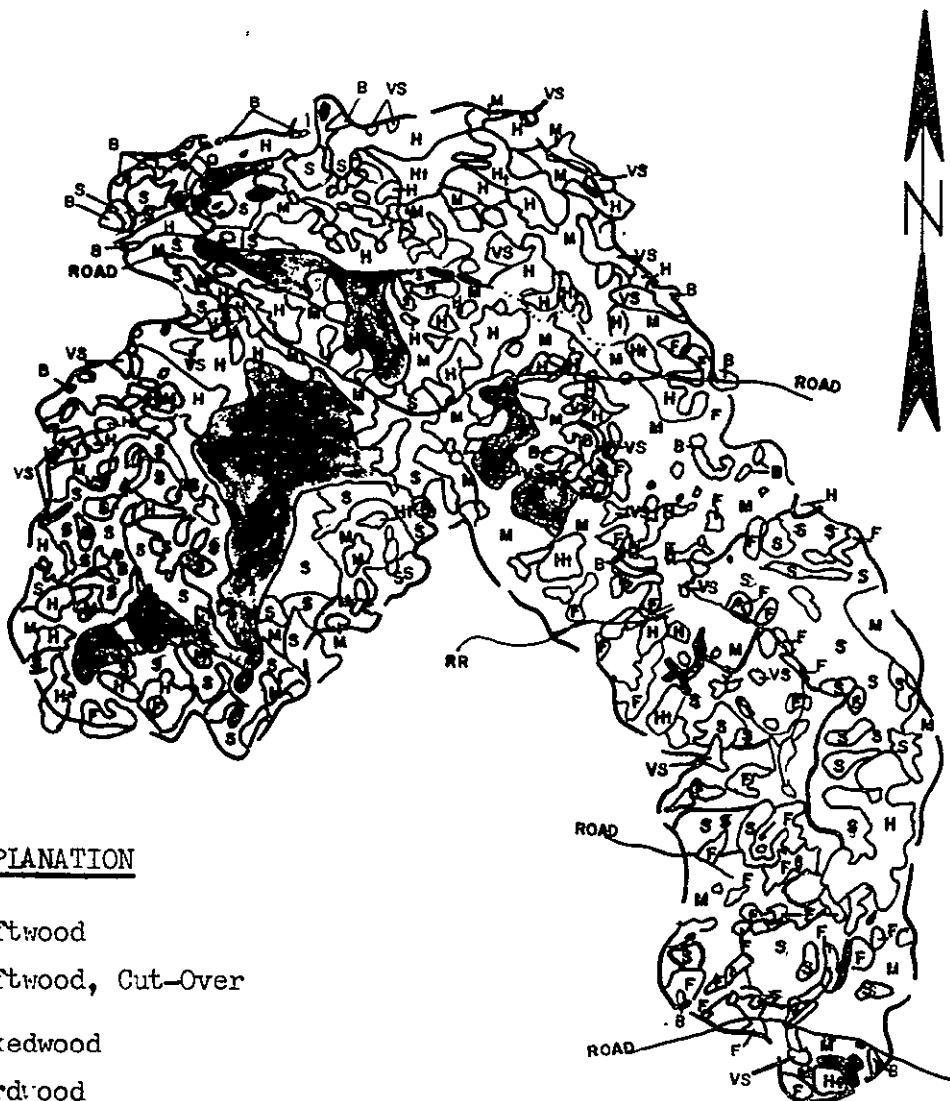
WATER STORAGE

- H_t - Heath Swamp (Sedge and Low Bush)
- S_s - Softwood Swamp
- H_s - Hardwood Swamp

Scale 1:125,000

TUNK STREAM WATERSHED VEGETATION COVER TYPES

**Determined From
SI90A COLOR , 21 SEPTEMBER 73**



EXPLANATION

FOREST

- S - Softwood
- S₁ - Softwood, Cut-Over
- M - Mixedwood
- H - Hardwood
- H₁ - Hardwood, Cut-Over

NON-FOREST

- V_s - Sparse Vegetation
- F - Field and Pasture
- B - Barren Ground (Plowed field, Pit, Excavation, Exposed Bedrock)

WATER STORAGE

- Ht - Heath Swamp (Sedge and Low Bush)
- Ss - Softwood Swamp
- Hs - Hardwood Swamp

Scale 1:125,000

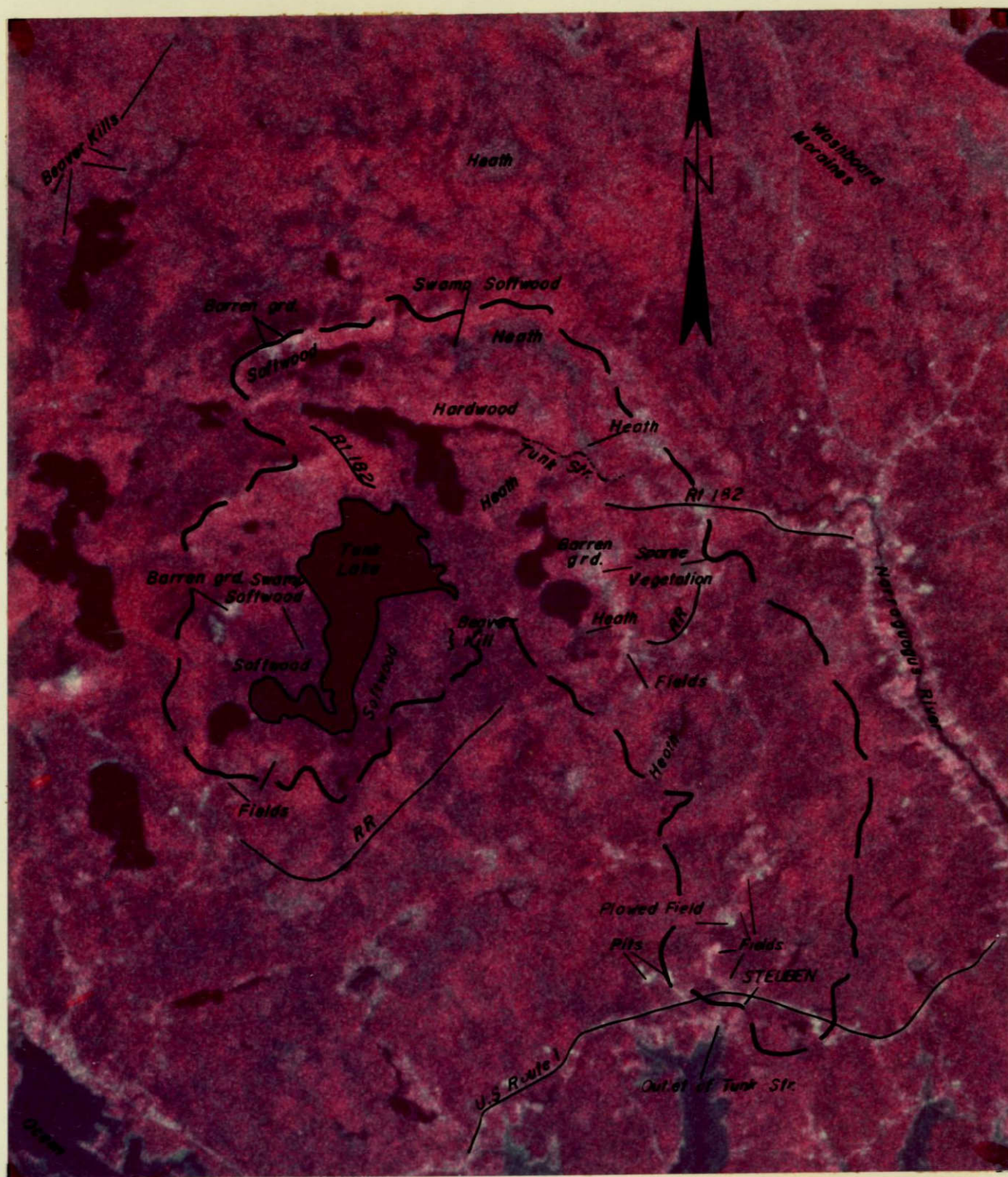
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TUNK STREAM WATERSHED

VEGETATION COVER TYPES

Determined From

SI90A COLOR INFRARED, 21 SEPTEMBER 73



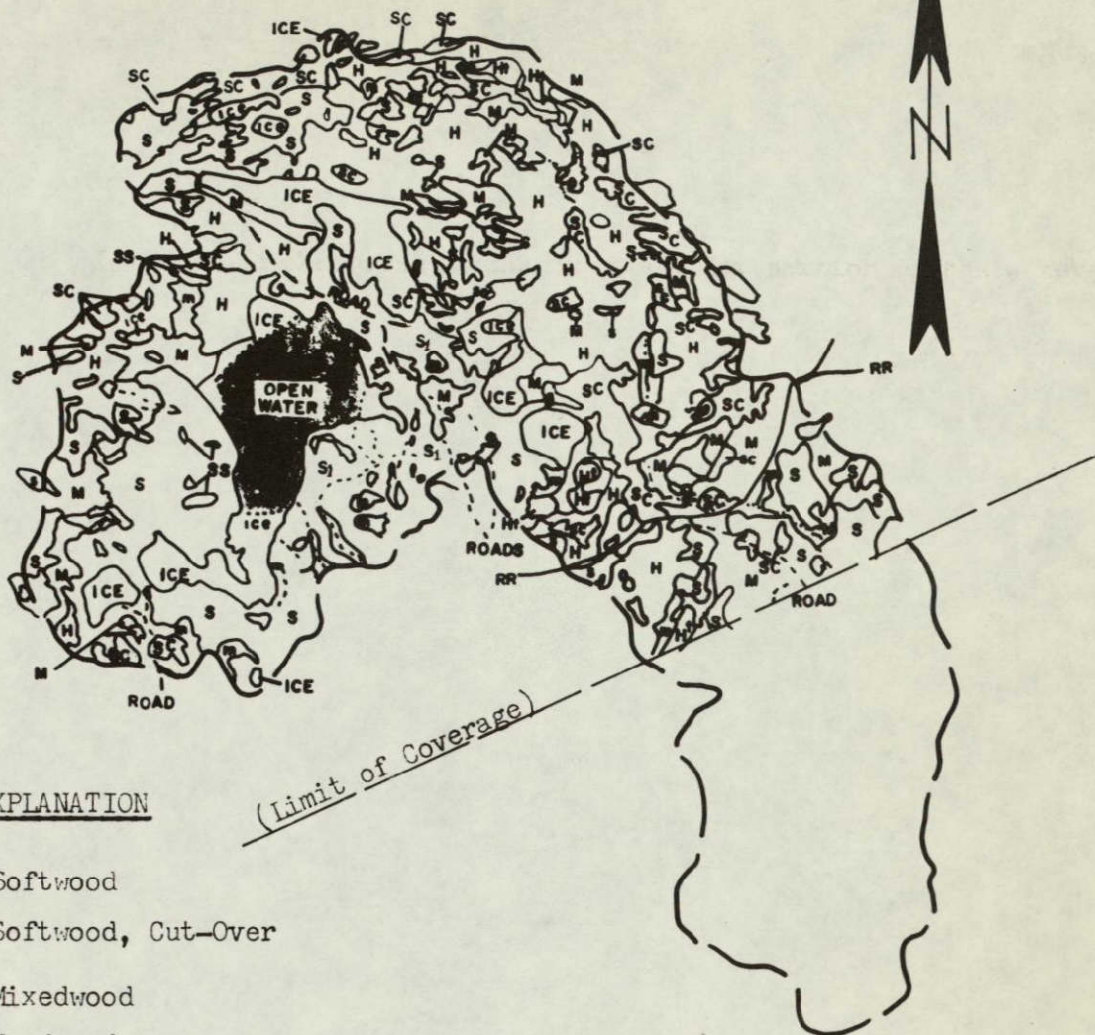
1:125,000

OVERLAY TO COLOR PRINT OF SI90A AEROCHROME IR COLOR SCENE 310, ROLL 45, SEPT. 21, 1973, OF TUNK STREAM WATERSHED AT STEUBEN, MAINE. RIDGE LINE IS FROM USGS 15-MINUTE TOPOGRAPHIC MAPS. GENERAL VEGETATION TYPES ARE INDICATED BY BLUE AND MAGENTA HUES, BUT GRAININESS INHIBITS PRECISE UNIT DELINEATIONS. SEVERAL TYPE UNIT LOCATIONS ARE INDICATED. WASHBOARD MORAINES IN DEBLOIS (NE QUADRANT) ARE NOT EVIDENT. COMPARE WITH FIGURE 19.

bodies could be located on the S190A CIR photography, but major streams were located only at their broadest portions.

Figure 18, the map developed from the study of high-resolution S190B Aerochrome Color IR photography, includes a major portion of the watershed. The scene was imaged January 14, 1974, when the ground was mantled with five to six inches of snow. All water bodies were ice-covered, with the exception of a large portion of Tunk Lake. Because of the snow cover, it was anticipated that softwood stands would be the most obvious type unit, having a well-defined dark magenta signature contrasting with the much lighter open areas. A 91 percent agreement of softwood areas was achieved. Hardwood areas imaging a greyish-green, were well contrasted with surrounding areas, and showed 88 percent agreement with the ground truth. The agreement of heath units was only 30%, attributable in part to some masking of low bush by snow cover.

It will be noted from inspection of figure 19, an 8X color print of the S190B CIR, that no graininess is present, resulting in very good resolution, unit boundary definition and visibility of fine detail. Comparison of this photograph and its overlay with the S190A CIR print and overlay (Figure 17) reveals the greater clarity of detail of the grain-free S190B film and the resulting better accuracy of plot of terrain features. As an example, logging roads having widths of about twenty feet are visible only on the S190B high-resolution photography. The only mis-interpretation of a major road was a four mile section of Route 182 that coincides with a bedrock lineament (refer to Figures 17 and 19 overlays).



EXPLANATION

FOREST

- S - Softwood
- S₁ - Softwood, Cut-Over
- M - Mixedwood
- H - Hardwood
- H₁ - Hardwood, Cut-Over

NON-FOREST

- V_s - Sparse Vegetation
- F - Field and Pasture
- B - Barren Ground (Plowed field, Pit, Excavation, Exposed Bedrock)

WATER STORAGE

- HT - Heath Swamp (Sedge and Low Bush)
- SS - Softwood Swamp
- HS - Hardwood Swamp
- SC - Snow Covered

Scale 1:125,000

TUNK STREAM WATERSHED VEGETATION COVER TYPES

Determined From

SI90B COLOR INFRARED, 14 JANUARY 74

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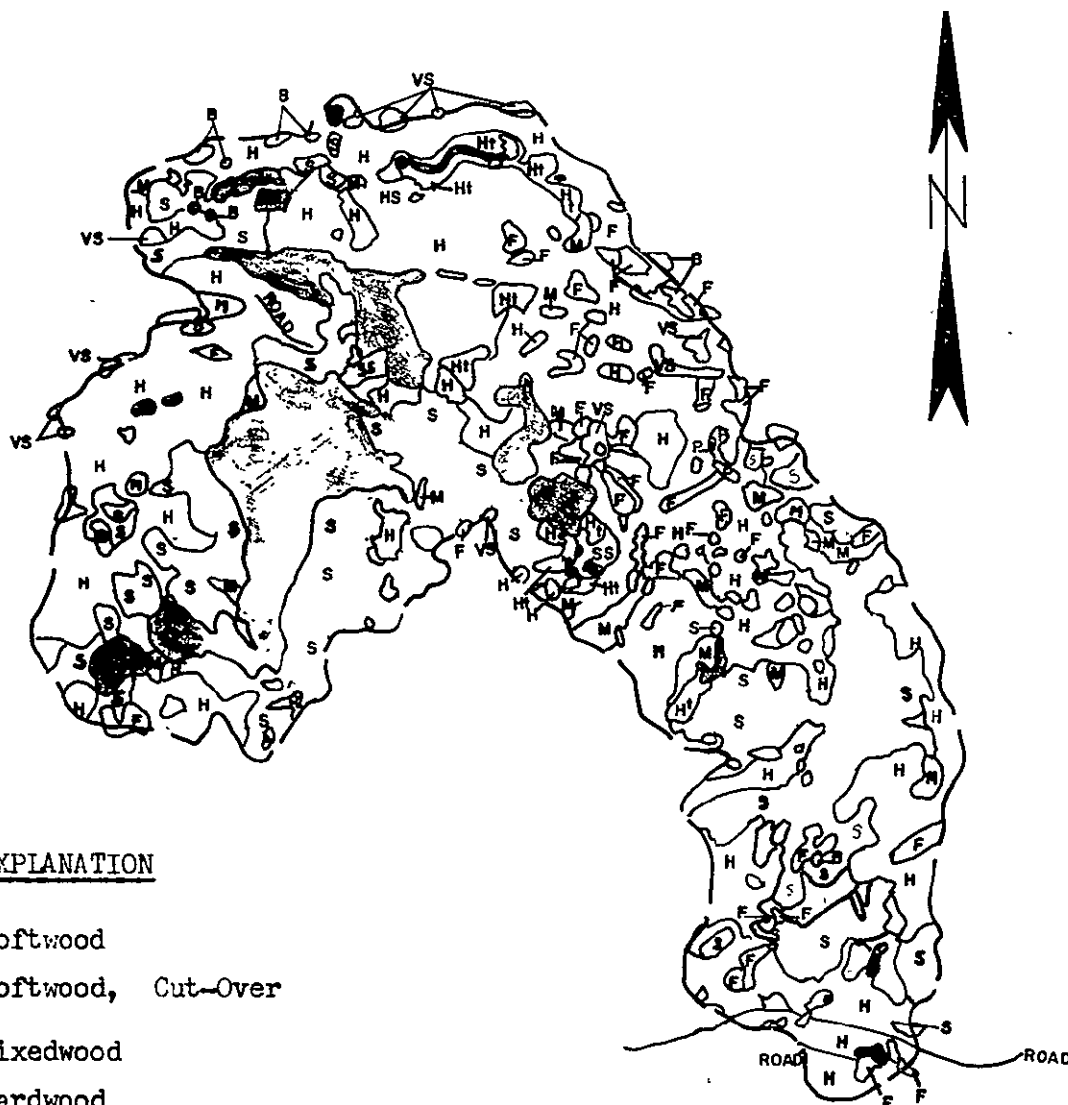
OVERLAY TO COLOR PRINT OF S190B HIGH-RESOLUTION AEROCHROME IR COLOR SCENE 032, ROLL 93, JANUARY 14, 1974, OF TUNK STREAM WATERSHED AT STEUBEN, MAINE. RIDGE LINE DELINEATED STEREOSCOPICALLY FROM SCENES 032 AND 033. SOFTWOOD STANDS IMAGE DARK MAGENTA, HARDWOOD STANDS ARE LIGHT BLUISH GREEN. MOST HEATHS ARE SNOW-COVERED, BUT ONE LARGE AND SEVERAL SMALL HEATH AREAS IMAGE A TAN SHADE NEAR THE NORTH RIDGE LINE. IDENTIFICATION OF MORAINES, ESPECIALLY THE WASHBOARD MORAINES IN DEBLOIS (NE QUADRANT), IS AIDED BY LOW SUN ANGLE AND SNOW ENHANCEMENT. COMPARE WITH FIGURE 17.

Figure 20 is the cover type map derived from LANDSAT-1 simulated color infrared imagery of 1 September 1972 and 1 October 1973. Agreements of forest type units with the ground truth are generally good, being 84 and 87 percent respectively for softwood and hardwood areas. Swamp units, conversely, had low correlations of only 25 and 30 percent, due primarily to their small sizes and locations adjacent to forest units, from which they were difficult to distinguish. It should be noted that the watershed area studied for the LANDSAT-1 report (Stoeckeler, et al, 1974) contained substantially different proportions of cover types than the Tunk Stream SKYLAB study watershed, including over 20 percent large low bush heaths. Correlations to ground truth for heath and swamp areas were correspondingly better in that LANDSAT study, where the units were larger and therefore more easily distinguished from adjacent forest stands.

The watershed ridge line was delineated stereoscopically on two bands of SKYLAB photography, U-2 CIR photography and LANDSAT-1 imagery to determine the relative accuracy that might be achieved on each media, compared to the U.S.G.S. 15-minute topographic map delineation as a standard. Figure 21 shows the relative forms and relationships of the delineations plotted to the common scale of 1:125,000. By the dot-grid method, the goodness of fit of delineations to the standard was determined as follows:

<u>MEDIA</u>	<u>DATE</u>	<u>PERCENT AGREEMENT</u>
U-2	24 Mar 1973	94
S190B	14 Jan 1974	93
S190A	14 Jan 1974	92
LANDSAT-1	22 Jan 1973	83
	10 Feb 1973	

Winter scenes of all imagery were used. Topographic enhancement by low sun angle and snow cover proved beneficial to the placement of the ridge.



EXPLANATION

FOREST

- S - Softwood
- S₁ - Softwood, Cut-Over
- M - Mixedwood
- H - Hardwood
- H₁ - Hardwood, Cut-Over

NON-FOREST

- V_s - Sparse Vegetation
- F - Field and Pasture
- B - Baren Ground (Plowed field, Pit, Excavation, Exposed Bedrock)

WATER STORAGE

- Ht - Heath Swamp (Sedge and Low Bush)
- Ss - Softwood Swamp
- Hs - Hardwood Swamp

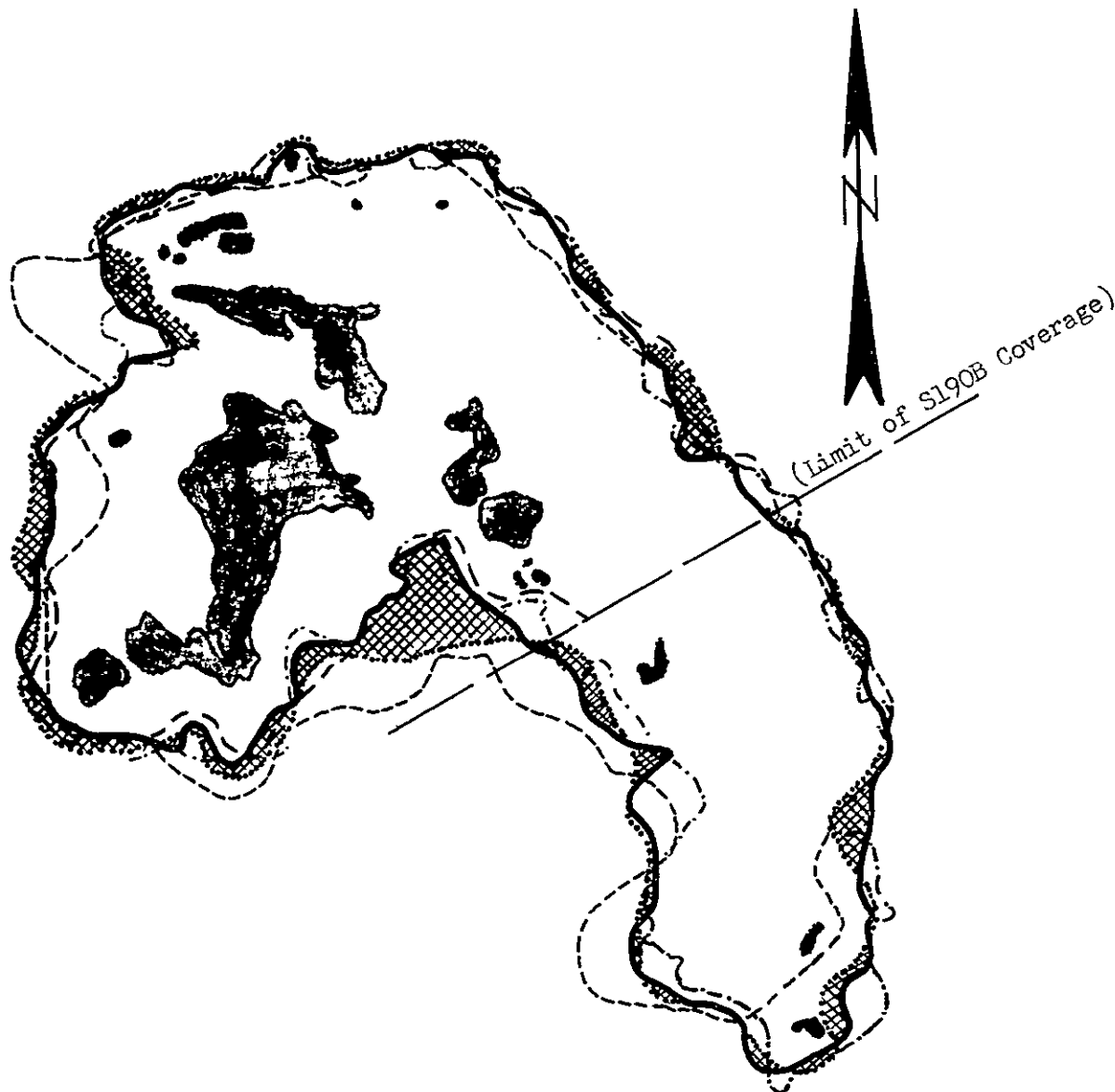
Scale 1:125,000

TUNK STREAM WATERSHED

VEGETATION COVER TYPES

Determined From

ERTS-I COLOR INFRARED, 1 SEPTEMBER 72
1 OCTOBER 72



EXPLANATION

- U.S.G.S. Topographic Map; Scale 1:62,500
- - - - - U-2 RC-10 (CIR), 24 Mar 73; Scale 1:125,000
- — — S190B (CIR), 14 Jan 74; Scale 1:500,000
- S190A (Color), 14 Jan 74; Scale 1:750,000
- - - - - ERTS-1 (CIR), 22 Jan 73 and 10 Feb 73; Scale 1:1,000,000

NOTE:

HACHURING INDICATES AREAS OF
DISAGREEMENT BETWEEN S190A
DELINEATION AND TOPOGRAPHIC
MAP BASE

TUNK STREAM WATERSHED

Comparison of Ridge Line Delineations
Achieved Stereoscopically on Four Remote
Sensing Media.

Scale 1:125,000

line by stereoscopic examination. Attempts to delineate the watershed on S190A 21 September 1973 photography were less accurate than on any of the winter scenes.

An example of a disagreement of the ridge line delineated with ground truth is illustrated on Figure 21, where it can be seen that the S190A derived line lies generally outside the base line. Similar dissimilarities occurred with the S190B and U-2 delineations. Agreement, except that of the LANDSAT line, are considered good, and are within the allowable tolerance of error for acreage or square mile computations for a large watershed. It will be noted that percent agreements show slight progressive improvement proportional to the increase in scale size of the detection media.

TABLE IV SUMMARY OF GOODNESS OF FIT OF VEGETATION COVER TYPES BY PERCENT AGREEMENT WITH GROUND TRUTH

NC=NO CORRELATION MADE:MEANINGFUL
DISTINCTION NOT ACHIEVED ON FILM TYPE

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	SI90A, 21 SEPT. 73				SI90B, 14 JAN. 74 CIR (0.5-0.88um)	CIR LANDSAT-1
	IR (0.7-0.8um)	PAN X (0.6-0.7um)	COLOR(0.4-0.7um)	CIR (0.5-0.88um)		
<u>FOREST</u>						
S - SOFTWOOD	71	NC	NC	90	91	84
H - HARDWOOD	NC	NC	NC	86	88	87
<u>NON-FOREST</u>						
Vs- BARREN GROUND SPARSE VEGETATION } COMBINED	NC	83	83	76	NC	86
F - FIELD and PASTURE	NC	88	76	85	NC	76
ROADS and RIGHTS OF WAY	NC	89	79	56	90	30
<u>WATER STORAGE</u>						
Ht- HEATH SWAMP (SEDGE & LOW BUSH)	60	85	85	81	60	66
Ss- SOFTWOOD SWAMP	NC	NC	NC	12	30	30
Hs- HARDWOOD SWAMP	NC	NC	NC	20	NC	25

NOTE: A 64 DOT PER SQUARE INCH GRID WAS USED TO COUNT AREAS OF AGREE -
MENT AND DISAGREEMENT. THE CATEGORIES OF SPARSE VEGETATION & BARREN GROUND
WERE COMBINED IN ORDER TO HAVE A SUFFICIENT DOT COUNT. THERE ARE NO
URBAN AREAS WITHIN THE WATERSHED. CUT-OVER SOFTWOOD AREAS WERE INCLUDED
IN THE SOFTWOOD COUNT. SNOW COVER WAS NOT COUNTED. (SI90B FILM ONLY.)

Discussion and Conclusions

The study of the Tunk Lake Stream watershed using very small scale CIR photography, the only film type available, of medium to high resolution for the typing of generalized ground cover characteristics pertinent to drainage data input is feasible and is desirable when good cloud-free seasonal coverage is available. The synoptic overview of the entire area of interest provided on one or two stereo models is distinctly advantageous for such a study, and also for the delineation of watershed ridge lines. When adequate data are obtainable from the scenes, the use of a rather cumbersome series of large-scale photos can be avoided. Ideally, however, good satellite coverage of the entire state should be available, obtained during the spring and/or fall seasons.

For the delineation of vegetation cover types and cultural features, as applied to hydrologic data in Maine, the S190B high-resolution film has provided the best data from a single source, in spite of the fact that only winter coverage was available for this study. It is unfortunate that no other season of photography from the ETC camera could be used for analysis. The best results for the delineation of forest types, and small cultural features present in a generally wilderness area, were achieved by stereoscopic interpretation of the S190B film, even with a six inch ground cover of snow. High percentages of correlations for all types of vegetation cover would result from the analysis of early spring and/or early fall coverage. The study of the S190B CIR winter scenes indicates, that with multiseasonal coverage, land use identification would equal the capabilities of the U-2 RC-10 photography.

Comparisons of the S190A camera products indicate that the station 3 film, Aerochrome IR Color, is generally the best for vegetation type interpretation,

especially for forest stands. This film and station 5 coverage (Panatomic-X Aerial B & W) would allow fairly good delineation of most categories, approaching the capabilities of the S190B system. The study of stations 1 and 2 photography (IR Aerographic B & W) indicates that it contributes very little data to this study discipline. The B & W IR scenes have an objectionable mottling, apparently inherent in film densities, particularly in the original 70mm format of station 2 film. After enlargement, the density differences, or mottled appearance, become more evident where continuous shades should be present, such as in large water bodies.

Station 4 films (Aerial Color) also contributed little data. Station 6 film (Panatomic X Aerial B & W) tends to have low contrast compared to the station 5 product. Very similar categories are imaged on both films, and the higher contrast of station 5 film allows better delineation.

Table V shows comparisons of agreement, by percent, of the various films and of ERTS imagery to the ground truth data. S190A photography is generally superior to the LANDSAT imagery. Two seasons of LANDSAT imagery were available for study. In the ERTS Hydrologic Study, spring high water conditions greatly aided the identification of swamp areas. Multiseasonal coverage by S190A photography would considerably upgrade its potential for cover type detection.

The agreement of ridge line locations, derived stereoscopically from S190A, S190B, and U-2 photography, with the topographic map base line are very good (page 54; figure 21, page 56). The relatively poor agreement of the LANDSAT delineation is attributable to the extremely small scale and to the lack of adequate parallax registered by scenes from adjacent orbits, resulting in difficulties of accurate line placement.

TABLE V. COMPARISONS OF RELATIVE PERCENT AGREEMENTS
OF COVER TYPES, AS DETERMINED FROM SATELLITE IMAGERY,
WITH GROUND TRUTH DATA

COVER TYPE	LANDSAT-1 CIR	S190A*	S190B CIR
S	84	90 (CIR)	91
H	87	86 (CIR)	88
V _s	86	83 (Color)	NC (Snow Cover)
F	76	88 (Pan X)	NC (Snow Cover)
Roads	30	89 (Pan X)	90
Ht	66	85 (Pan X) (Color)	60
Ss	30	12 (CIR)	30
Hs	25	20 (CIR)	NC (Snow Cover)

*Camera Station Film Having Best Agreement

At the present state of the art of the requirements of land use parameters for hydrologic studies, it is believed that land use and cover type data for large watersheds can be derived from the evaluated aircraft and satellite systems. Large watersheds, in the context of highway design considerations, are considered to be those of 1000 acres or more.

The majority of pipes and structures serving the Maine highway system accomodate runoff from watersheds of less than one square mile. As determined from this study, the decreasing order of desirability for accuracy attainable is U-2, S190B, S190A and LANDSAT remote sensing products. The S190B high-resolution film, if ever available on a multiseasonal basis, would fulfill the projected requirements of future needs, based on the limited coverage studied to date.

GEOLOGY/GEOMORPHOLOGY

Background and Introduction

Investigation utilizing aerial photographs and photo interpretation techniques have been conducted by the Maine Bureau of Highways for the location and evaluation of glacial granular formations since 1954. Color and color infrared photography has been available for some localized areas since 1966, utilized on an experimental basis with standard black and white coverage. Materials inventory regional reports are then prepared for inclusion in detailed soils reports for all major highway projects. A large quantity of ground truth information has therefore been compiled in the form of airphoto, field and laboratory data relative to glacial landforms, obtained for several hundred materials studies and currently on file in the Materials and Research Division of the Bureau of Highways.

The glacial granular formations within Maine are the State's largest and primary mineral resource. The economic importance of sand and gravel deposits to the Bureau of Highways and to the construction industry has long been recognized. As early as 1930, without benefit of aerial photography, a comprehensive survey of the glacial road materials of the State, and including sands and gravels useful for building construction, was initiated by the University of Maine in cooperation with the Maine State Highway Commission. (Leavitt and Perkins, 1934). The survey, covering 70% of the State, is still a very useful reference for investigators.

A cooperative study to correlate the relationships of natural features of eskers and associated terrain discernible on airphotos with materials in the deposits was conducted by the Maine State Highway Commission and the U.S. Bureau of Public Roads during the 1960-63 field seasons. (Gunn, 1961; Woodman, 1962; Stoeckeler, 1964). Several possible criteria for predicting quality and quantity from airphoto interpretation were investigated, with

good to inconclusive results.

In addition to highway related studies, much work has been done by early explorers and by the academic community. Hitchcock (1862) and Stone (1899) recognized the surficial glacial features of the State and, to a degree, their economic importance. Trefethen (1944) studied the lithology of eskers and recognized the generally local origin of materials. Borns (1965) has interpreted glacial stratigraphy to correlate the geologic sequence of events within Maine and adjacent areas. Goldthwait (1949) and Bloom (1960) have studied marine clays and sea level fluctuations, and correlated them with glacial and post glacial granular deposits within the State. Additional work by these and others has also contributed greatly to the knowledge of Maine's Pleistocene epoch.

There is, then, a vast storehouse of data available regarding Maine's glacial deposits, published and unpublished. The majority of formations, large and small, are recognized and known, except for those that may exist in the State's northwestern wilderness area.

With the advent of the ERTS and SKYLAB programs, it was thought that various small scale diagnostic features of satellite imagery could be (1) used to detect glacial landforms by photo interpretation methods, and (2) compared with other imagery types, scales and formats to determine optimum extraction of data. The scope of the ERTS proposal was to (1) develop a landform classification system for small scale imagery, (2) compile a surficial geologic map of Maine with emphasis on economic glacial deposits, and (3) apply the data to on-going and future materials inventory studies.

LANDSAT-1 imagery was studied in stereo and pseudo stereo relief in the sidemap portions, by photographic and projected enlargement, color-enhancement, color projection, by false color composite transparencies and prints, and by density slicing. Varying degrees of success were achieved by each method.

U-2 support aircraft underflight photography was a valuable ground truth source. Standard photo interpretation techniques using existing M.D.O.T. equipment was the primary method of data extraction. The original proposal funding, scope and objectives assumed that earth features diagnostic of glacial landforms could be delineated from the small scale imagery and aid in the production of on-going materials studies.

General viewing of broad features was accomplished on LANDSAT imagery and some smaller formations were identified, mainly on winter scenes and where snow cover and low sun angle served to enhance linear topographic forms. Detail essential to the development of a landform classification system was lacking. For the methods employed, resolution and registration of LANDSAT imagery was inadequate for identifying and mapping small landform units. Formations and deposits of economic importance to specific highway projects are often very limited in extent, and these were generally not identified. Large features such as extensive esker and moraine formations were located, with prior knowledge of their existence.

During the LANDSAT study it was recognized that the synoptic aspect of high altitude imagery and photography might be utilized to gain a better understanding of the overall correlations of glacially related or produced geomorphic features. The current knowledge of glacial features within the state is abundant, ranging between mostly unpublished localized detailed work for highway use and published academic broad-based studies (Borns, Calkins, Goldthwaite, etc.) From the study of small scale U-2 photographs in conjunction with LANDSAT-1 investigations, the general trends of esker systems and their associated deltaic deposits and outwash plains became more evident. The relationship of the large moraines of the eastern coastal region to

sea level changes and to inland formations could also be observed on one or two scenes, with current topographic maps used for relative elevation determinations. In the relatively unexplored northwest portion of Maine, large areas of lacustrine sediments are known to exist, indicative of glacial lake deposits laid down near the end of the Pleistocene epoch. Caldwell (1959) and others have investigated the properties and derivation of these silts and clays, and to some degree, their areal extent. Again, with the availability of small scale scenes imaging several hundred square miles, it was anticipated that SKYLAB photography might afford a good look at these extensive deposits.

The original objectives outlined in the Geology portion of the SKYLAB proposal include developing a glacial landform classification system, delineating glaciofluvial deposits and incorporating information gleaned from satellite imagery into a surficial geologic map of Maine. It is also stated that tentative objectives may be modified after the satellite imagery is analyzed. In view of the limited identification results for small features realized from LANDSAT imagery, and the improved identification capabilities for large features anticipated from 'first look' viewing of SKYLAB photography, a somewhat different approach to the study of geomorphology was pursued. A more realistic and academic study of overall formation identification and relationship is believed justified for this report. Ground truth for the surficial geologic study consists of previous work by Borns and others, in the form of sketch maps and generalized formational trends and associations, derived from both detailed and reconnaissance field work, materials inventory data in the MDOT files, conventional large scale photography and small scale high altitude U-2 (RC-10) photography obtained during 1972 and 1973 missions flown for the LANDSAT-1 and SKYLAB proposals.

Figures 22 and 23 indicate the regions of study in two geomorphic sections of the state and the SKYLAB photography used for analysis. S190A photography obtained September 10, 1973, was analyzed for the western area, Figure 22, lying within the Upland Section of the New England Geomorphic Province. S190A and S190B photography obtained January 14, 1974, was analyzed for the eastern area, Figure 23, lying principally within the Seaboard Lowland Section.

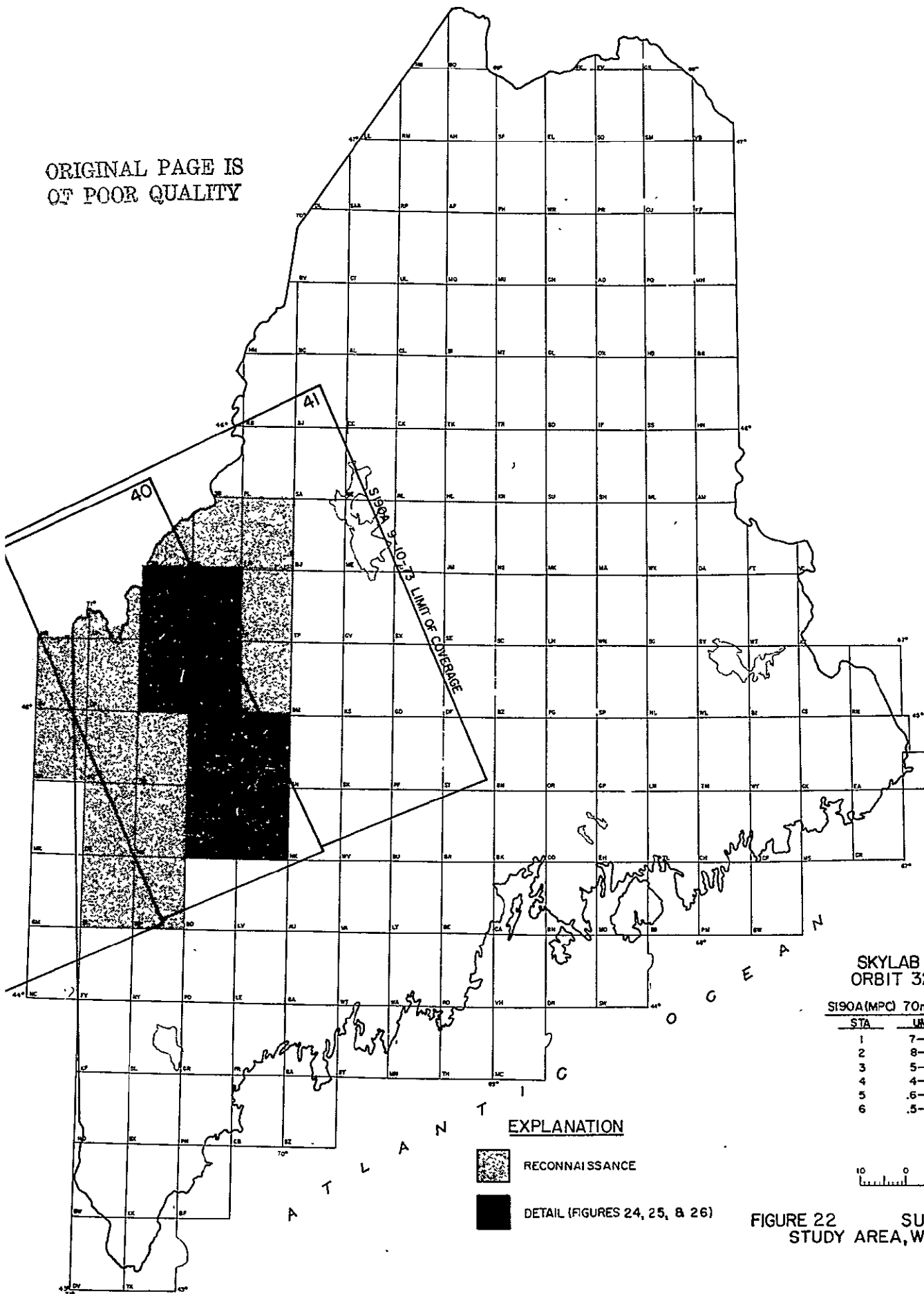
Techniques

Standard airphoto interpretation techniques were used to analyze SKYLAB photography for the detection, identification and delineation of surficial features. Stereo viewing of photography was done with an Abrams Model CB-1 2-4 stereoscope, an Old Delft scanning stereoscope and a Bausch and Lomb Zoom 95 Stereoscope. Visual enlargements to 40X were achieved with the B & L instrument. Black and white paper enlargements of most scenes, generally at the scale of 1:250,000, were produced in-house and used for study, with specific areas of interest enlarged to 1:125,000. Analysis of projection enlargements, utilized for the other discipline studies, was not effectively used for the study of land forms.

For the study of glaciofluvial and related deposits in western Maine, only S190A photography obtained 9/10/73 was available. For the eastern section, S190A and S190B coverage of 1/14/74 and partial coverage by S190A of 9/21/73 was available. The S190B was first analyzed, before using the S190A for both regions. Standard 15-minute U.S.G.S. topographic quadrangle maps were constantly referred to in conjunction with the photo studies.

Reconnaissance surficial maps for comparison purposes were compiled from U-2 and conventional scale photography, supplemented by available M.D.O.T. materials inventory data. Conventional photography scales ranged between 1:12,000 and 1:43,000. Using the data gleaned from the airphoto maps, the

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SKYLAB S190A
ORBIT 32,940-73

S190A(MPCI) 70mm 1:3,000,000

STA	UM	FILM
1	7-8	IR B&W
2	8-9	IR B&W
3	5-88	IR COLOR
4	4-7	COLOR
5	.6-7	B & W
6	.5-6	B & W

EXPLANATION



RECONNAISSANCE



DETAIL (FIGURES 24, 25, & 26)

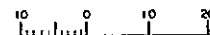
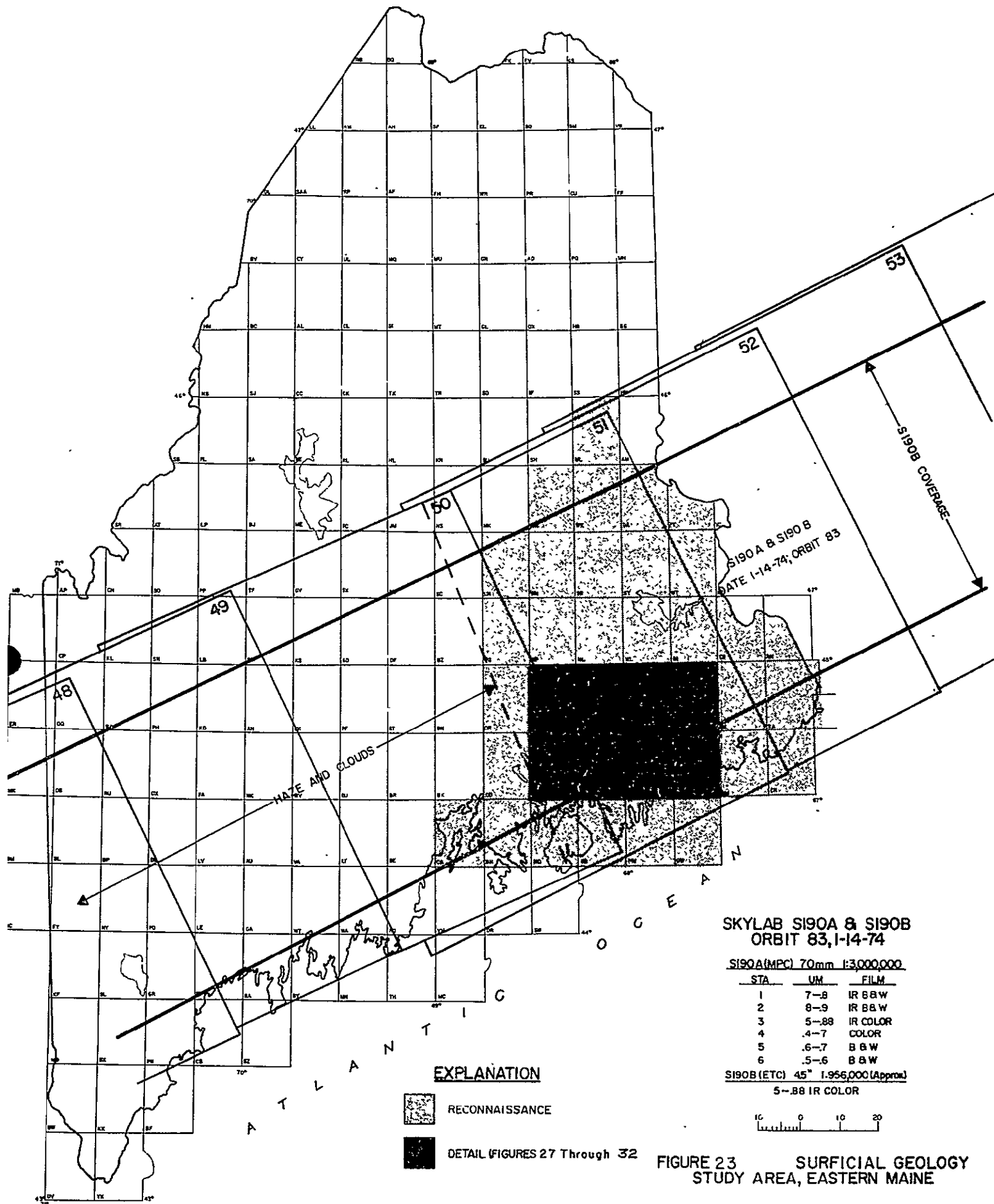


FIGURE 22 SURFICIAL GEOLOGY
STUDY AREA, WESTERN MAINE

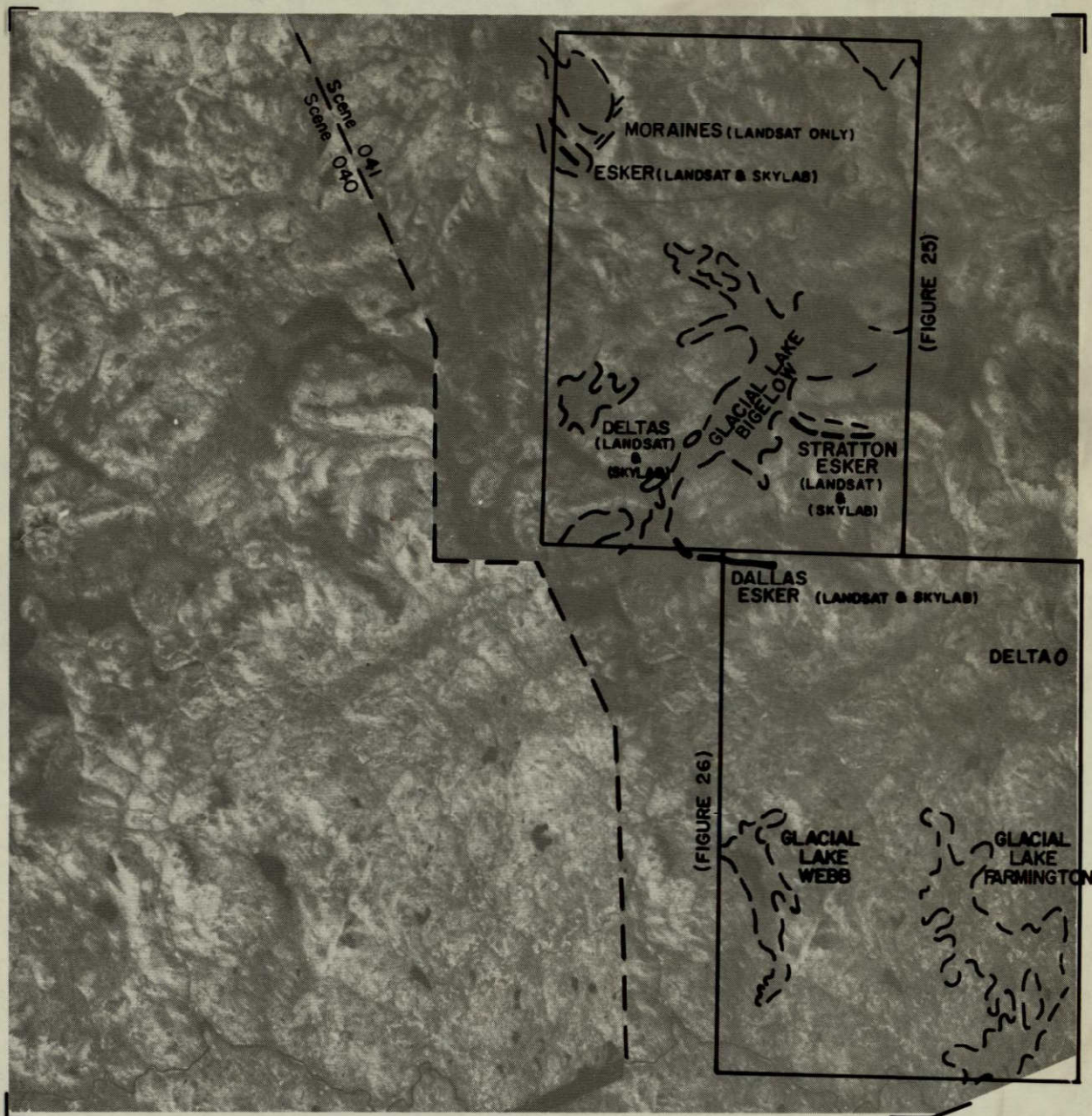


SKYLAB photos were restudied for a broad overview of landform features and their inter-relationships.

Surficial Geology, Western Maine Study Area

In the western study area, the mappable surficial features of glacial origin or association, other than till drift, are principally ice stagnation formations situated in the lowland intervalles or adjacent to watercourses in the hilly or mountainous terrain. The ice sheet was stagnated and undergoing mass wasting in the mountains of northwestern Maine until about 12,000 years ago. Glacier ice or wash debris dammed major meltwater streams for periods of time, forming water bodies and the subsequent deposition of glacial lake sediments. Kame terraces, kame fields, and crevasse fillings formed by transported debris associated with wasting ice are present, as are eskers and deltas, deposited from the vast volume of meltwater. Structural deposits associated with active ice are also present at generally higher elevations, such as drumlins, fluted till, stream-line terrain features and moraines on the north-facing slopes of the Boundary Mountains (Figures 24 and 25).

An area encompassing twenty-three U.S.G.S. 15-minute quadrangles and portions was initially scanned using the S190A photography of 9/10/73. Of this area, an eight-quadrangle block was studied in detail (Figure 22, page 68). The eight quadrangles are shown in Figure 24, a stereopair of S190A Station 2 photography (IR Aerographic B & W) enlarged to the approximate scale of 1:750,000. The locations of several features visible on the IR film are indicated on the overlay, and the general hilly and mountainous terrain of the region may be observed stereoscopically. Of particular note on the stereopair are the extensive areas of glacial lake sediments investigated by Caldwell (1959) in the Farmington area, imaging dark gray tones in the IR band photography. He correlated this clay, silt, and sand deposition in the



1:750,000

STEREOPAIR OF THE EIGHT-QUADRANGLE DETAIL SURFICIAL GEOLOGY STUDY AREA, WESTERN MAINE. IR AEROGRAPHIC B & W FILM, CAMERA STATION 2 (0.8 - 0.9 μ m), SCENES 040 AND 041, 9/10/73. GLACIAL LAKE SEDIMENTS OF GLACIAL LAKES FARMINGTON, WEBB AND BIGELOW ARE THE PREDOMINANT FEATURES, MAPPED FROM SKYLAB PHOTOGRAPHY. ICE CONTACT FORMATIONS MAPPED FROM SKYLAB PHOTOGRAPHY AND LANDSAT-1 IMAGERY ARE ALSO INDICATED.

Farmington Quadrangle to a glacially dammed water body referred to as Glacial Lake Farmington. The SKYLAB delineation of this formation appears to correlate very well with the ground mapping. A second area of apparent lacustrine deposition west of the town of Farmington has been mapped as Glacial Lake Webb, as yet unconfirmed by field investigations. To the northwest of Webb, however, field checks have confirmed the existence of SKYLAB-mapped lake sediments that image on the IR band the same as other mapped units in the region.

Glacial Lakes were also present in the Boundary Mountains (Shiltz, 1970), caused by the damming of drainage from the retreating ice sheet that formed the moraines detected on ERTS imagery on the north side of the mountains at the U.S.-Canadian boundary (also see Figure 25). Lake sediments in this region, also imaging dark gray tones in the IR band, may be seen in Figure 24, including Glacial Lake Bigelow which lies between the Boundary Mountains on the northwest and the Blue Mountain Range to the southeast. Several smaller glacial formations are also indicated on the photograph.

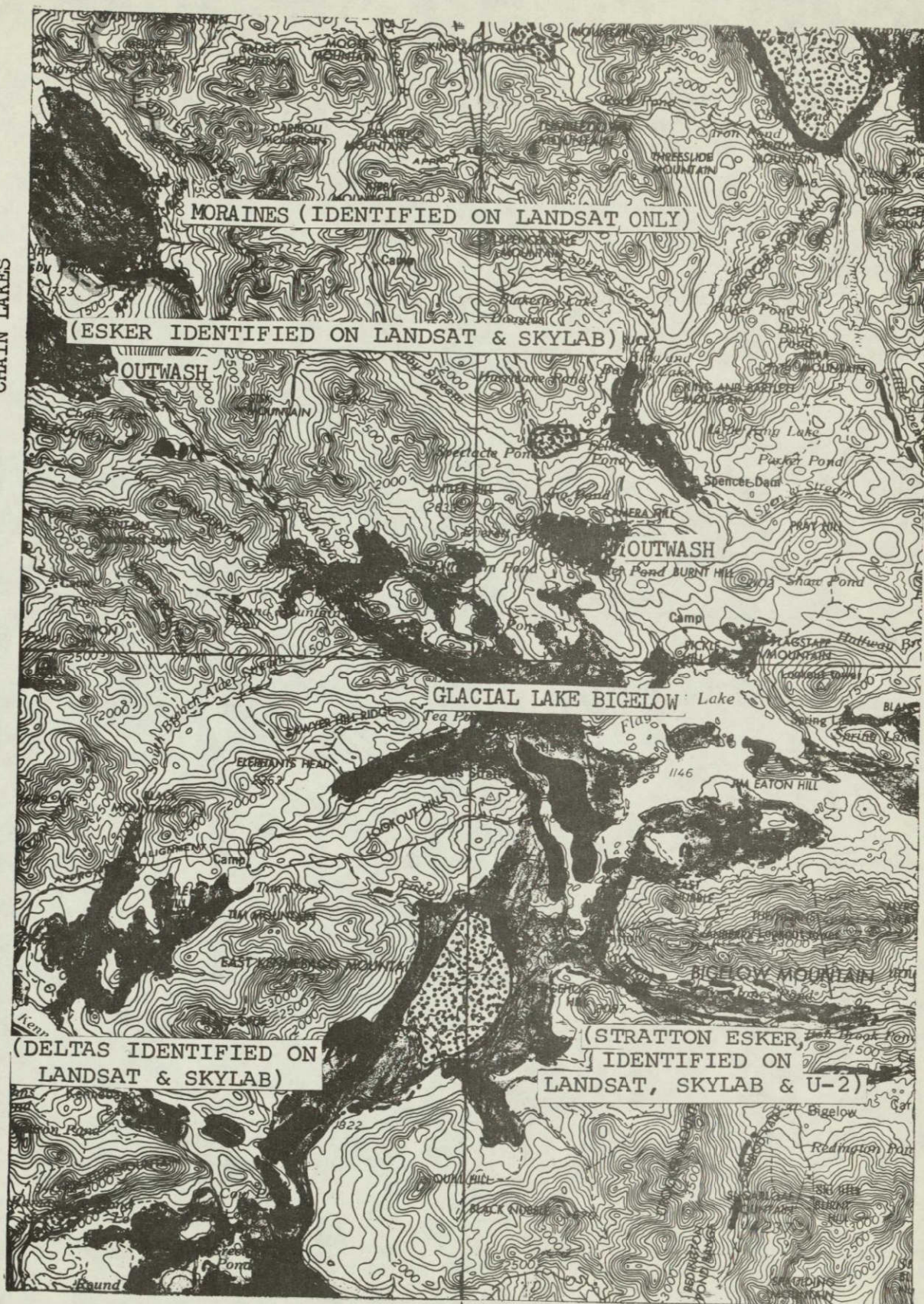
Figure 25 is a 1:250,000 scale topographic map of the northwesterly four quadrangles of the detail study area. Glacial lake sediments were delineated and mapped from SKYLAB S190A IR photography, and not identified on U-2 RC-10 photography. Ice-contact features could also be identified on LANDSAT-1 imagery, as indicated. Glacial Lake Bigelow was first recognized by Leavitt and Perkins (1935). From the interpretation of SKYLAB S190A photography, it appears that the lake sediments may be more extensive than originally mapped, confirmed by several field checks at the boundaries of the present delineation. Other areas of suspected glacial lake sediments, delineated in Figure 25, were subsequently verified by field investigations. The relationship of the sediments to their apparent origin by ice or detritus blockage of stream outlets in the Blue Mountain Range can be seen on this map and in Figure 24.

CHAIN LAKES

KENNEBAGO LAKE

SPENCER

STRATTON



1:250,000 (Match Figure 26)

EXPLANATION

- Lake Sediments
- Delta
- Esker
- Outwash
- Kame Field
- ▲ Moraine

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SURFICIAL GEOLOGIC FEATURES IN
THE NORTHWESTERLY FOUR QUADRANGLES
OF THE DETAIL STUDY AREA, WESTERN MAINE.
DELINEATIONS OF LAKE SEDIMENTS
ARE FROM SKYLAB PHOTOGRAPHY, OTHERS
FROM U-2 RC-10 PHOTOGRAPHY.

In addition to the areas of glacial lake sediments, the Stratton esker, Reddington-Dallas esker, the esker northwest of Chain Lake and some river valley deltas were also detected on the SKYLAB IR and are delineated on the map.

Figure 26 is a 1:250,000 scale topographic map with surficial features of the southeasterly four quadrangles of the detail study area. Glacial lakes sediments were mapped from SKYLAB S190A IR (Stations 1 and 2) photography. Glacial Lakes Farmington and Webb are visible in good detail. Many ice-contact features were mapped from U-2 RC-10 photography, as indicated. The only ice-contact feature seen on the SKYLAB 9/10/73 coverage is the Dallas-Reddington esker, in the NW quadrant. Outwash plains of the river valleys, eskers, deltas, kames, and fluted till features were delineated from U-2 RC-10 photography interpretations.

With reference to the mapping of glacial lake sediments from SKYLAB, spot checks of delineations have confirmed their presence in every case. The restrictions of time and finances have not allowed the definition of absolute limits. Their presence is apparently well defined on the B & W IR film (camera stations 1 and 2). Most of the areas are of more poorly drained soils, and they are topographically lower than adjacent formations. In addition, they generally support thick stands of softwoods which image the darkest shades, other than water bodies, in the IR bands. Spruce, alder and low bush vegetation in swamps image similarly, however, so that distinctions must be made and a certain amount of error in interpretation anticipated. Work in this discipline thus far has indicated that SKYLAB stereoscopic inspection, coupled with some ground truth, affords the means for the best synoptic definition of the extent of glacial lake sediments available at present.

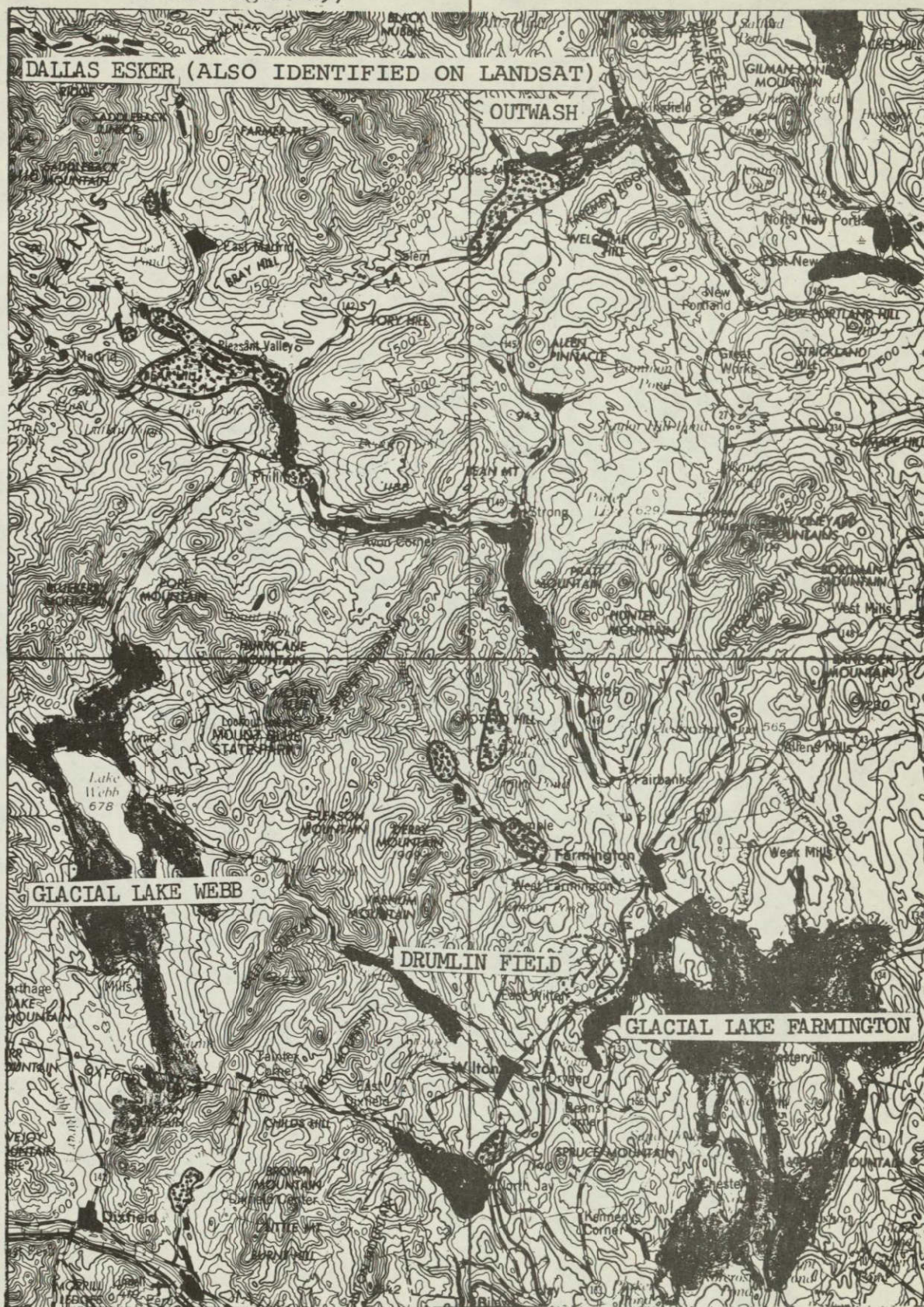
(Match Figure 25)

PHILLIPS

DIXFIELD

KINGFIELD

FARMINGTON



1:250,000

EXPLANATION

- Lake Sediments
- Delta
- Esker
- Outwash
- Kame Field

SURFICIAL GEOLOGIC FEATURES IN THE SOUTHEASTERLY FOUR QUADRANGLES OF THE DETAIL STUDY AREA, WESTERN MAINE. DELINEATIONS OF LAKE SEDIMENTS ARE FROM SKYLAB PHOTOGRAPHY, OTHERS FROM U-2 RC-10 PHOTOGRAPHY.

The detection of granular formations in the western study area has been relatively limited. Eskers having high relief, of a hundred feet or more, were seen, such as the Stratton and Chain Lakes deposits. However, most of the eskers in the region have considerably less relief. The lack of vegetation contrast is probably an inhibiting factor also. The Dallas-Reddington esker, supporting a stand of hardwood in a softwood swamp, is sharply outlined, but the majority of eskers in the region are less obviously situated. Generally, interpretation of terrain features and soil types is accomplished with greater ease and accuracy on imagery obtained in the spring or fall seasons when foliage is absent. The September photography of the western area, therefore, is not optimum for the detection of glaciofluvial formations. The large formations detected, other than lake sediments, can also be identified on 26 November 1973 LANDSAT imagery.

Surficial Geology, Eastern Maine Study Area

Contrasted with the intervale formations present in the western mountain terrain, coastal eastern Maine is dominated by ice contact features deposited from an active retreating ice front. Borns (1974) summarized the surficial geology and processes of the region:

"The fluctuating margin of the Late Wisconsin Laurentide Ice Sheet in Maine retreated approximately parallel to the coast leaving a belt of submarine end moraines (Borns, 1966, 1973). This recession was accompanied by a marine transgression of the coastal region that extended into the river valleys of central Maine (Goldthwait, 1949). Glaciomarine sediments up to approximately 150 feet thick were deposited in the coastal region. Inland of the end moraine belt central Maine is characterized by ground moraine, eskers up to 80 miles long extending to the southeast-facing slopes of the northeast-southwest-trending highlands of the state (Leavitt and Perkins, 1935) and glaciomarine sediments in the major river valleys.

The glacial geology of eastern coastal Maine is characterized by a northeast-southwest-trending 25 mile wide complex composed of hundreds of end moraines and associated features (Leavitt and Perkins, 1935; Borns 1966, 1967, 1973) deposited along a fluctuating glacier margin as it retreated northwest from a position on the continental

shelf. Most, and perhaps all, of these moraines were deposited below the sea level that prevailed at that time. Within the end-moraine complex as many as 20 local marginal fluctuations are recognized.

End-Moraine Complex

The end-moraine complex is characterized by hundreds of end moraines, but also includes ice-marginal kames and marine deltas and interlobate deposits.

Two types of end moraines are recognized; a large, stratified and relatively continuous type in contrast to the more numerous, small non-stratified and discontinuous "washboard" type. The large moraines are often up to 60 feet high, 300 feet wide with segments continuous for up to 10 miles in length. Internally these are composed predominately of stratified sand and gravel with minor interbeds of compact till and fossiliferous marine silts. Commonly these deposits have been deformed by ice push from their proximal sides which, coupled with the cross-cutting lobate map-pattern of the moraines, indicates that the moraines formed along the margin of an internally active ice sheet. These moraines are very similar in composition and origin to the Ra and Central Swedish moraines of Scandinavia.

The majority of the smaller and more numerous type of moraine seldom exceed 10 feet in height, 30 feet in width, and 0.5 mile in length. Commonly they occur in clusters of up to 50 parallel curved and evenly spaced moraines and hence the name "washboard" moraines. Nearly all of these moraines are composed of compact till. (See Figure 19, page 53).

The spatial and stratigraphic relationships of both types of moraines indicate that the larger stratified moraines formed during local readvances of the ice margin and that the smaller "washboard" moraines formed during the subsequent recessions. All the moraines found are below the upper marine limit and most probably formed below sea level.

The large volume of stratified drift within the large moraines and their wide distribution indicate that extensive melting of the ice sheet was prevalent and that while generally meltwater was discharging all along the ice margin local drainage concentrated large deposits of stratified drift as kames or marine deltas at the margin formed.

Marine Transgression

The recession of the ice sheet in the coastal and central sections of Maine was contemporaneous with a marine transgression. Evidence of both submergence and emergence is generally documented by the fossiliferous silty clay deposits of the region which form a discontinuous cover partially filling the valleys and lapping up on

the highlands to the altitude of the maximum postglacial marine submergence (Goldthwait, 1949). The marine sediment, named the Presumpscot Formation (Bloom, 1960), was deposited in the proximity of the receding ice margin as indicated by the ice-marginal deltas, inter-tongued marine sediments within the end moraines, the abundance of ice-rafted erratics, and by the cold water marine fauna within the sediment.

Pineo Ridge Readvance

The glacier recession that produced the coastal moraine complex was interrupted by an extensive readvance in eastern Maine that terminated in the sea at Pineo Ridge Moraine approximately 12,800 to 12,600 years ago (Borns, 1973)."

Figure 27 is a sketch map showing the general surficial geologic features of a large portion of the eastern study region and the areal relationships of the many ice-contact formations. SKYLAB photography and U-2 RC-10 photography provided a synoptic look at the area that allowed viewing of the regional formation patterns. The major trend of the moraines in the eastern section can be compared with the cross-cutting relationship of the northeast-southwest trending end moraines to the west. In back, or north, of the coastal moraines is a series of large deltas, and associated esker systems that extend for miles inland.

Figure 28 is a 1:250,000 scale topographic map showing surficial features delineated from SKYLAB photography of the westerly four quadrangles of the detail study area (Figure 23, page 69). The lobate patterns of moraine clusters are evident, formed along the frontal lobes of the receding glacier ice. An interesting pattern of "herringbone" lineation of two sets of washboard moraines in the SW quadrant is more strikingly illustrated on the S190B photography than can be shown on a map. There is evidence of a small medial moraine, or interlobate formation, dividing the two lobate groupings.

The three major esker systems and associated deltas in the SW quadrant and north half of the map were easily identified on the S190B coverage

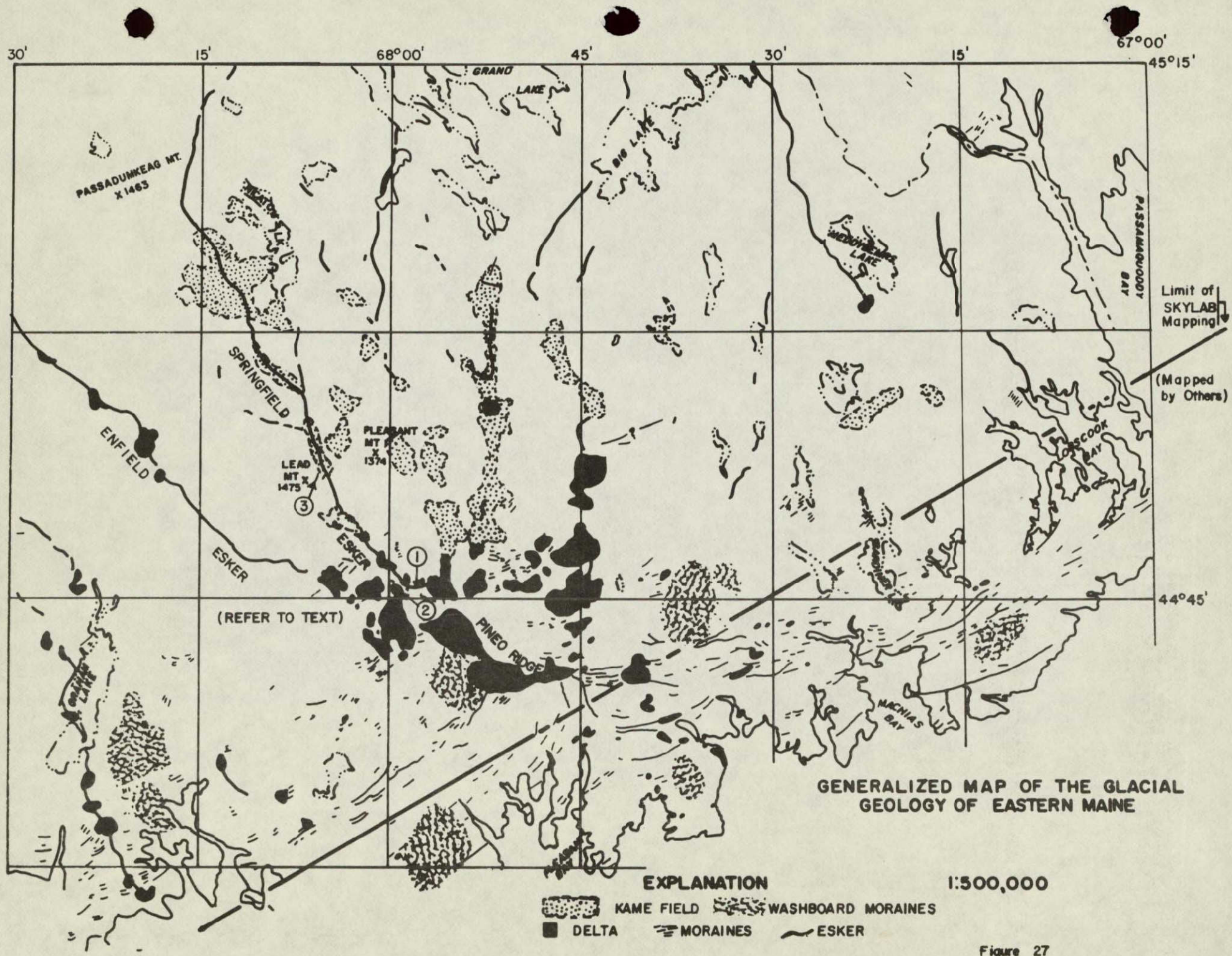
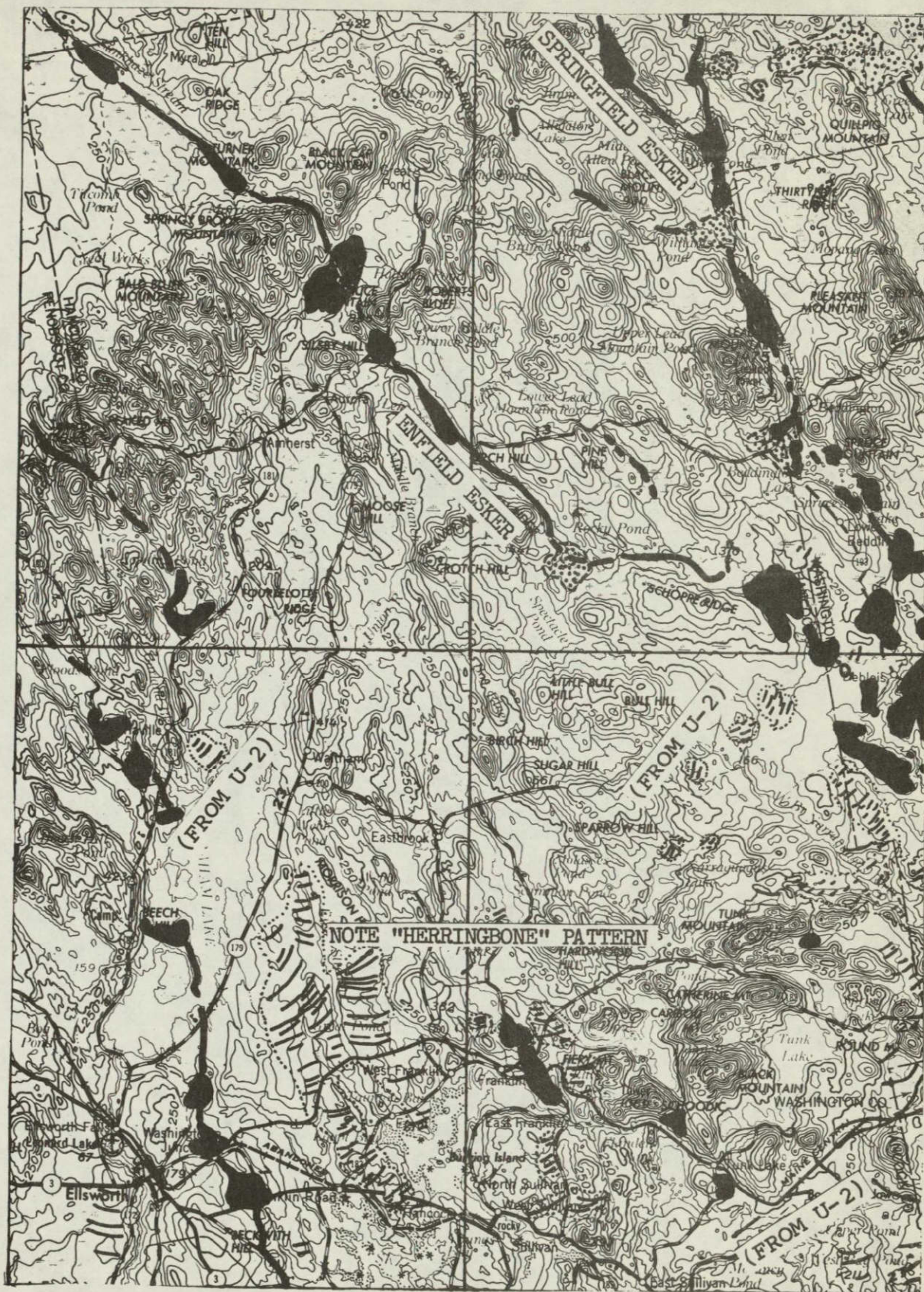


Figure 27

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GREAT POND

ELLSWORTH



LEAD MOUNTAIN

(Match Figure 29)

TUNK LAKE

1:250,000

EXPLANATION

- Delta
- Washboard Moraines
- Moraines
- Esker
- Outwash Plain
- Kame Field
- Ice Marginal Kame

SURFICIAL GEOLOGIC FEATURES IN
THE WESTERLY FOUR QUADRANGLES OF THE
DETAIL STUDY AREA, EASTERN MAINE.
DELINEATIONS ARE FROM SKYLAB AND
U-2 PHOTOGRAPHY.

Figure 28

of January 14, 1974. By comparison of photo identification with current U.S.G.S. topographic maps, it can be determined that the upper surface of individual deltas are at progressively higher elevations from the coast inland, indicating a rising sea level contemporaneous with the retreating ice front.

Figure 29 is a 1:250,000 scale topographic map showing surficial features delineated from SKYLAB photography and U-2 RC-10 photography of the easterly four quadrangles of the detail study area. (This illustration matches to the eastern border of Figure 28). In the southern half of the map are illustrated the regional trends and relationships of moraine lineations and delta deposition observable on S190B photography of January 14, 1974. The moraines lying in the coastal area are probably contemporaneous with the lobate clusters of moraines on the west. The moraines to the east indicate deposition from a different ice lobe and possibly from a readvance of the ice mass. The large deltas and eskers mapped near the center of the illustration, including the Pineo Ridge formation, are the last deposits formed, and seem to cross-cut both sets of moraines.

As noted, only B & W IR film was ultimately used for the evaluation of surficial features in western Maine, where only September S190A photography was available. Photography of the selected study area in eastern Maine included S190A coverage of September 21, 1973, and S190A and S190B of January 14, 1974. The S190A was studied in single station stereo models and station combination models. Detection levels ranging between very good and poor were realized from this comparison experimentation. Winter multispectral photos tend to image very minor differences of terrain, with snow-covered areas being more subdued in the IR bands than in color or PAN-X.

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(Match Figure 28)

CHERRYFIELD

TUG MOUNTAIN

WESLEY

COLUMBIA FALLS



1:250,000

EXPLANATION

- Delta
- ▨ Washboard Moraines
- Moraines
- \\ Esker
- ▭ Outwash Plain
- ▨ Kame field
- ✱ Ice Marginal Kame

SURFICIAL GEOLOGIC FEATURES IN
THE EASTERLY FOUR QUADRANGLES OF THE
DETAIL STUDY AREA, EASTERN MAINE.
DELINEATIONS ARE FROM SKYLAB AND
U-2 PHOTOGRAPHY.

Figure 29

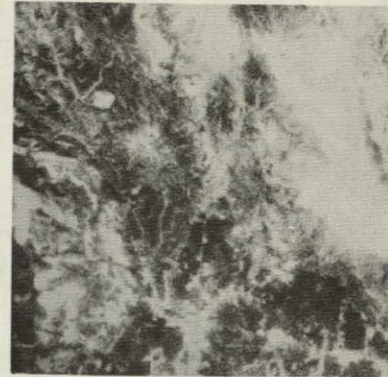
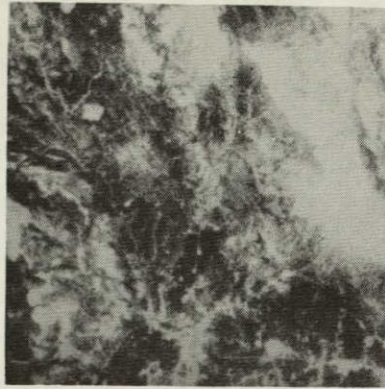
No difference was detected between the IR Aerographic films of stations 1 and 2, both of which had about the same detail and graininess when enlarged.

Figure 30 contains comparison stereopairs of station 2 film (IR Aerographic B & W), Figure 30A, and station 5 film (Panatomic-X Aerial B & W), Figure 30B, both enlarged photographically 19X to the approximate scale of 1:158,000. The graininess of the station 5 product is just becoming evident at this scale, whereas the IR print is exceedingly degraded for interpretation purposes.

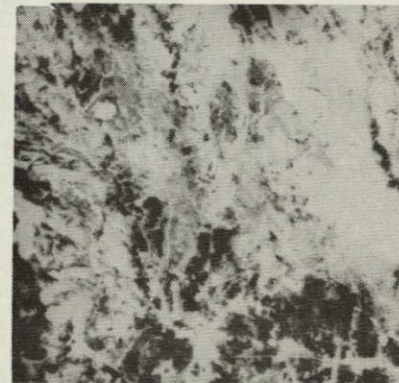
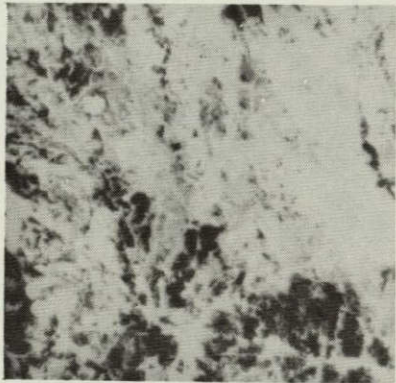
The station 5 film, Panatomic-X B & W, is considered to have the best detail, or resolution for interpretation, of all the S190A products. The CIR film, station 3, is considered to be slightly better than that of IR B & W, but has low detail and excessive graininess when enlarged. The station 4 film (Aerial color high-resolution) has improved detail potentials and facilitates interpretation. Station 6 film (Panatomic-X Aerial B & W, 0.6-0.7 μ m) seems to be slightly less in detail potentials than the similar station 5 film, appearing 'flat' and having less contrast.

The detection of granular formations on S190A summer film in the eastern region has been about the same as described for the western area (page 76). Very few of the glacial features were detected on the S190A coastal coverage of September 21, 1973. In Figure 17, page 50, an area of washboard moraines exists in the NE quadrant of the illustration, indicated on the overlay, but their presence is obscure. Enlargements of stations 1, 2, 5, and 6 also have degrees of graininess.

The S190B photography of the eastern study region was obtained in the winter, but for this discipline investigation it surpasses the S190A summer coverage. Detail approaching that of U-2 photography was discernable, and the greater synoptic quality affords a unique opportunity for areal



[A] SL90A STA. 2 FILM: IR AEROGRAPHIC B & W (0.8 - 0.9 μm)



[B] SL90A STA. 5 FILM: PANATOMIC-X AERIAL B & W (0.6 - 0.7 μm)

STEREOPAIRS OF 1/14/74 PHOTOGRAPHY SHOWING A WASHBOARD MORaine COMPLEX SOUTHWEST OF PINEO RIDGE. BOTH ARE 8.25 X ENLARGEMENTS TO THE SCALE OF 1:345,000. THE MORaine RIDGES ARE BARELY DISCERNIBLE IN STEREOPAIR A, DUE TO THE EXTREME GRAININESS OF THE FILM. THE BETTER RESOLUTION OF STEREOPAIR B IS OBVIOUS. COMPARE WITH FIGURES 17 and 19.

studies. In Figure 19, page 53, the washboard moraine area in the NE quadrant is very apparent.

Figure 31 is a black and white stereopair of prints made from S190B color infrared film, enlarged to the scale of 1:225,000. The same washboard moraine complex imaged in both color prints (Figures 17 and 19) can be seen clearly on these photos, and the superior quality of the S190B film becomes apparent when compared to the Panatomic-X prints of Figure 30B.

LANDSAT imagery was also used for this study for comparison purposes. Woodman (1973), referring to LANDSAT-1 imagery being viewed stereoscopically for glacial formations, observed:

"Three-dimensional viewing of mountainous areas and associated rock structures is excellent. Features in more subdued topography, however, are much less obvious, and only the more prominent formations are discernible by relief difference. Glacial formations are detected mainly by the existence of excavations, which may image differently than fields, and by prior knowledge of their occurrence.

Sequential orbital imagery generally produces better three-dimensional viewing. Tonal differences within imagery obtained eighteen to thirty-seven days apart and within the same season are often reinforced to provide added detail for the observer, and the stereo effect is adequate. However, extreme tonal differences in images of a stereopair, such as summer-winter or winter-spring, usually produce a confusing scene of high contrast to the observer, that tends to obscure detail.

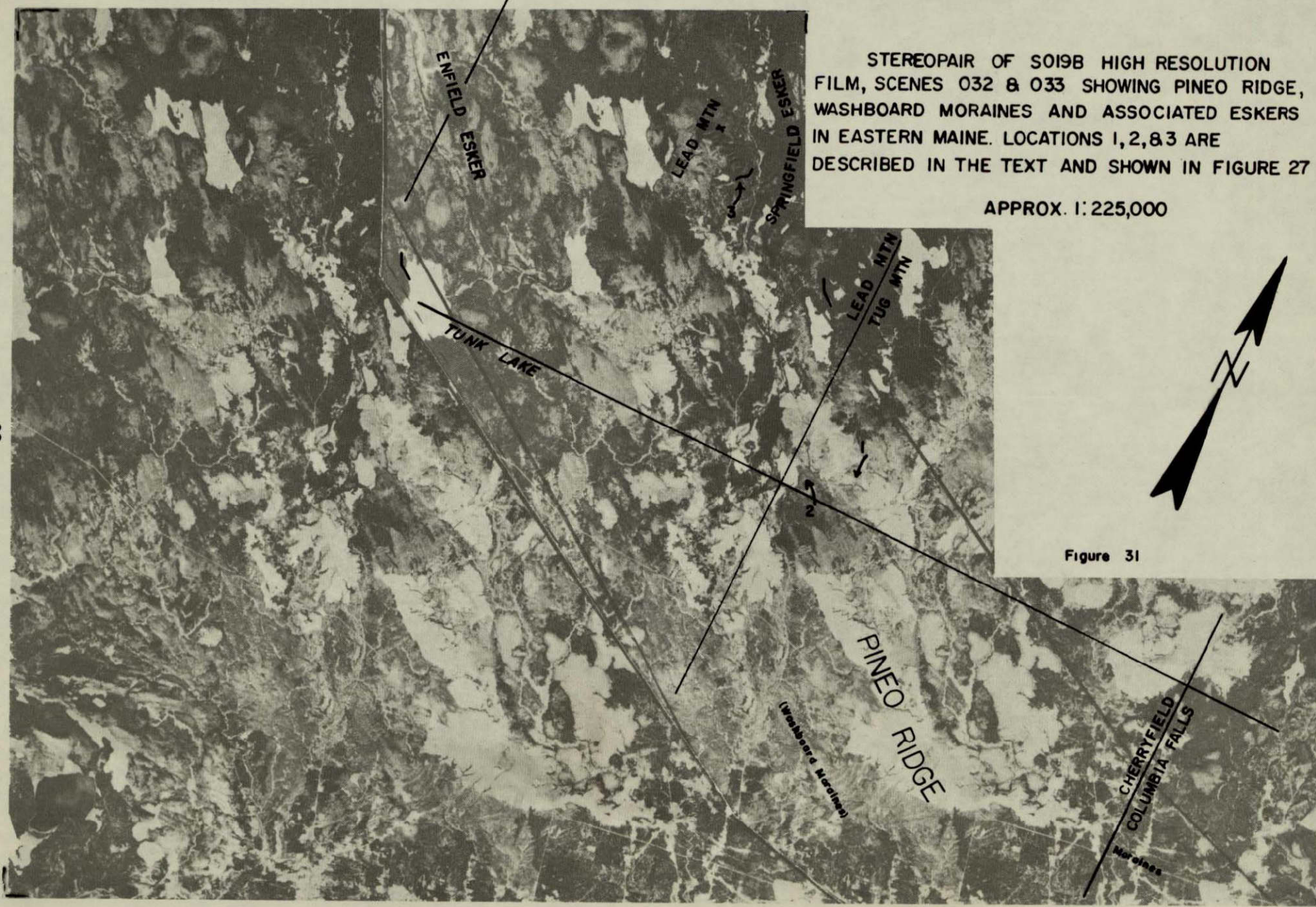
Winter imagery, especially of the more sparsely settled areas of the State, is often preferable to summer imagery for landform detection, as snow cover tends to produce an 'edge effect' enhancement of smaller relief features. This was also observed in monocular image projection studies.

In general, band 5 is found to be superior for landform and granular excavation detection, when such features are of large enough area and/or relief to be identified. For the purposes of this study, other bands tend to show less detail. Band 5 used with band 4 or 6 in a stereogram is found to have little added enhancement or stereoscopic value.

C-2

86c

98



STEREOPAIR OF S019B HIGH RESOLUTION
FILM, SCENES 032 & 033 SHOWING PINEO RIDGE,
WASHBOARD MORAINES AND ASSOCIATED ESKERS
IN EASTERN MAINE. LOCATIONS 1,2,&3 ARE
DESCRIBED IN THE TEXT AND SHOWN IN FIGURE 27

APPROX. 1:225,000

Figure 31

Apparent stereo relief is very often attained by viewing two spectral bands of the same image. This pseudostereo effect is due to tonal variations and differing spectral imaging within the scene, and found to be helpful for the delineation of some formations."

The washboard moraines imaged in the above referred figures could not be detected on ERTS-1 imagery. The resolution of these features by ERTS-1 imagery is very similar to the S190A B & W IR film (Figure 30A). In summary, the S190B high resolution winter photography is judged to be the best product for this discipline study, followed by S190A Panatomic-X Aerial B & W film.

Specific Glacial Problems Relative to Eastern Maine

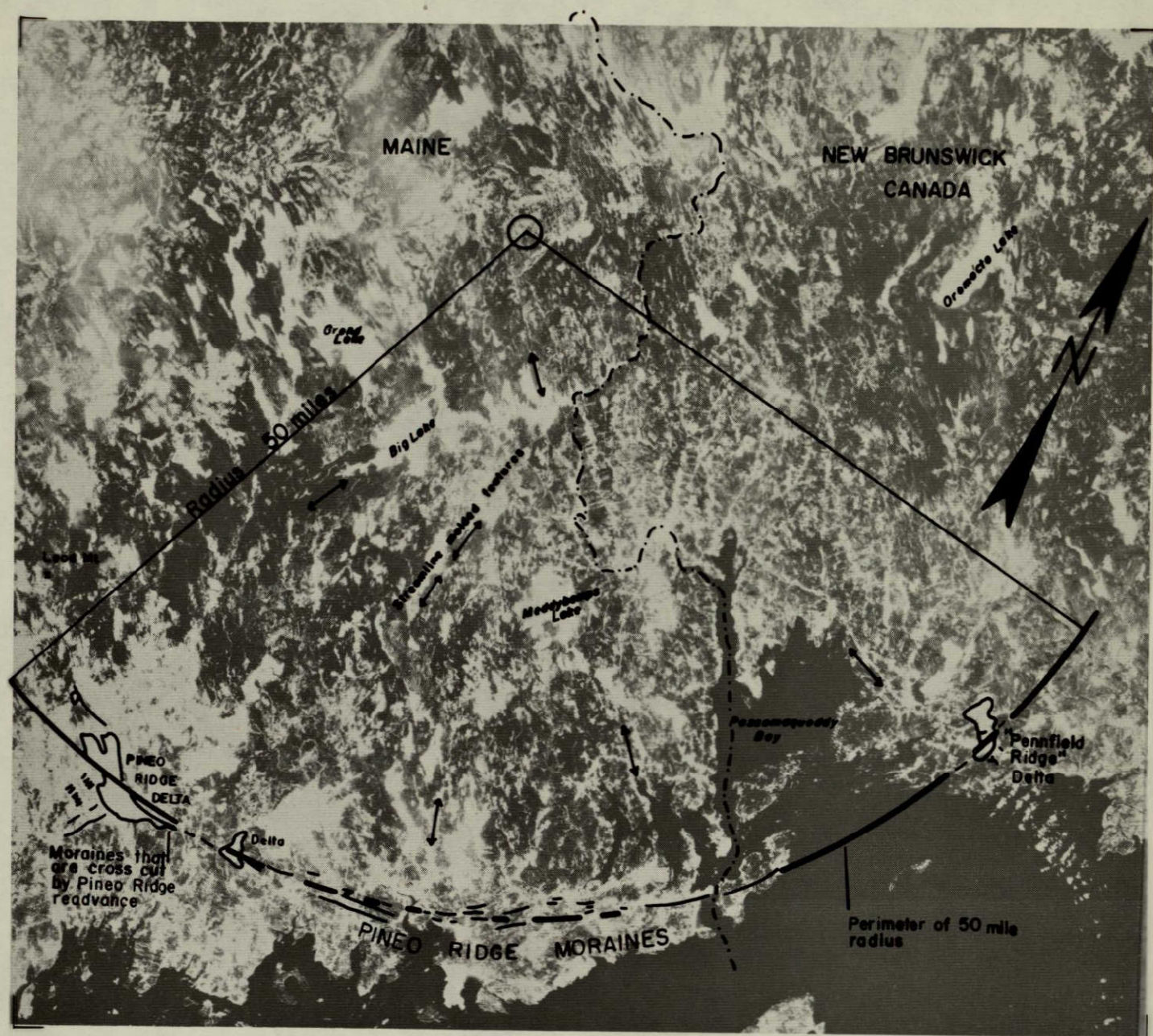
A general understanding of the retreat of the Late Wisconsin ice sheet in eastern Maine has been established by Borns and others, but several problems remain. The complex relationship between sea level and the position of the ice fronts is not clearly defined. The relationship of massive esker systems north of the coastal moraine belt to ice readvance is not clear. A major formation, the Highland Front moraine, on the northwest of the New England Highlands is dated 12,600 years B.P.* The Pineo Ridge Moraines are dated 12,700 years B.P. (Borns, 1967). Moraines are also known to exist northeast of Mount Katahdin in the valley of the East Branch of the Penobscot River (Woodman, 1973). The relationship between these moraines and the Pineo Ridge ice front is not clear. Marine sediments in the Penobscot River Valley are dated about the same as Pineo Ridge and the earlier moraines that are cross cut by the Pineo Ridge readvance, but the position of the ice front relative to the Penobscot Valley embayment is not clear. The study of SKYLAB photography has contributed data to aid in resolving some of these questions:

*Before Present

(1) Two large esker systems in the SE quadrant of the Lead Mountain quadrangle, referred to as the Enfield and Springfield Eskers, show positional relationships to the moraine and delta complexes (Figure 27, page 73, and Figure 31, page 86). The Enfield esker appears to be related to the earlier moraines that are cut by the Pineo Ridge moraines and deltas. The Springfield esker was originally believed to be related to the same ice front that formed the earlier moraine, placing the Pineo Ridge Lobe clearly to the east of this esker. On SKYLAB photography it can be seen that the Springfield esker lies in back, or north, of the Pineo Ridge moraines, location 1 on Figures 27 and 31. This indicates that the Pineo ice front must have terminated east of the Enfield esker but west of the Springfield esker.

(2) The Pineo Ridge readvance terminated in the sea, forming delta surfaces at 260 foot elevations above present sea level. A study of deltas using the S190B photos and current U.S.G.S. topographic maps of the region revealed the presence of previously unrecognized delta surfaces at the 260 foot elevation. One such delta was located along the trend of a possible continuation of the Pineo Ridge front, location 2 on Figures 27 and 31. Additional inspection of S190B for this trend to the northwest indicates a moraine formation at the base of Lead Mountain, location 3, on Figures 27 and 31, where the ice front was against the southeasterly flank. Thus, the Pineo Ridge ice front appears to extend for at least an additional twelve to fifteen miles to the northeast. Inspection of large scale photography tends to support these hypotheses.

(3) Figure 32 shows a radial pattern developed from the study of S190A Station 4 film and Panatomic-X Station 5 film that seems to indicate the nature and direction of flow of a lobate ice front.



ATLANTIC OCEAN

1:750,000

OVERLAY TO A PRINT OF SKYLAB S190A PANATOMIC-X FILM (STA.5) SCENE 053, ROLL 71, JANUARY 14, 1974, OF EASTERN COASTAL MAINE. THE UNOBSTRUCTED RADIAL FLOW OF A LOBATE ICE FRONT IS SUGGESTED BY THE SKYLAB-DETECTED STREAMLINE TERRAIN FEATURES (ARROWS) PARALLEL TO THE RADIALS, AND ALIGNMENT OF DELTAS AND MORAINES. THE CONTINUOUS ARC OF MORAINES AT PASSAMAQUODDY BAY INDICATES THAT THE SEA HAD LITTLE EFFECT ON THE ICE FRONT.

It appears that the Pineo Ridge moraines and deltas occur in a large arc having a radius of fifty miles, extending into Canada to include the Pennfield Ridge delta in New Brunswick. Detected formations are situated in the proper positions along the arc line. The trend does not continue westerly because of the presence of hills and mountains exceeding 1000 feet in elevation, including Lead Mountain. The majority of streamline features detected on SKYLAB photos, namely molded till and gouged bedrock, are parallel to radials drawn from the hypothetical center. The implications of this apparent large radial pattern are that ice flow was uniform and uninhibited by obstacles in this region, that it was possibly a surging ice lobe and that lowland areas such as Passamaquoddy Bay had little influence upon the readvancing ice, where calving of the ice at sea level was not rapid enough to retard the advance of the ice front. The station 4 film (color) allowed the best viewing.

During the study of S190A and S190B photo coverage of the eastern region, numerous points of interest were noted for possible future study. The limitations of time and finances have restricted this report to the events described. It should be noted that all events cited were subject to multistage examination, where SKYLAB photos were studied and specific areas then examined in detail on large scale conventional photography. Ideally, field checking of key locations should eventually be carried out.

SUMMARY

Fourteen S190A frames and nine S190B frames imaging the State of Maine, or portions thereof, were ultimately received for the pursuits of this multidisciplinary study. Six of the S190A frames in central Maine were obtained in January and three of these have partial cloud obscuration. All of the S190B scenes were obtained in the winter. Each of the discipline investigations was, therefore, tailored to locations within the State where it was felt that the best coverage occurred to satisfy the discipline criteria, and where some existing ground truth could be utilized. This necessitated altering the original concepts of the proposal, since it was anticipated that the same areas studied in the ERTS-1 (LANDSAT) studies would be investigated using the SKYLAB products. It is believed, however, that adequate comparisons of the two satellite systems and conventional photography were eventually achieved.

Following 'first look' at the 70mm S190A photography and 4.5 inch S190B transparencies, 4X enlargements of select scenes in paper print, transparency and negative format of the S190A and 2X enlargements of S190B were requested from Johnson Space Center. These were generally received within reasonable time limits so that in-house enlargements and slides could be made for the various study purposes.

The unfortunate serious illness of the original principal investigator, Ernest Stoeckeler, caused some uncertainties and delays in the investigative procedures. It finally became apparent that the work would have to be carried out without his services. Had he been able to function as the P.I., the final report would probably differ somewhat from its present form but we believe that the original objectives and intent have been adequately covered within the framework of available SKYLAB coverage and remote sensing media.

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It should be noted that some objectives contained in the original proposal are not covered in this report, due to the absence of certain SKYLAB instrumentation products. No geographical investigations were performed, as no thermal imagery was received, and no monitoring of any discipline subject was possible, as no repetitive coverage of the state was obtained.

Investigative procedures for all disciplines stress photo interpretation methods and comparisons with LANDSAT imagery and conventional photography. SKYLAB films are evaluated objectively as to what the principal investigators believed to be the best product, from personal experience and observations. It is recognized that a vast number of interacting variables exist that influence all phases of a multidisciplinary study, ranging from personal acuity and expertise to changing ground conditions, film and filter combinations, day and hour of photography, and many others. To completely 'cover all bases' would be practically impossible, and certainly beyond the scope of this study.

CONCLUSIONS

The improved resolution of SKYLAB film products compared with LANDSAT imagery is a definite advantage for the study of terrain features using very small scale remote sensing media. The present lack of repetitive coverage by SKYLAB, however, does not permit the monitoring of dynamic changes, such as flood conditions, that is possible from cyclic LANDSAT coverage. The resolution and frame overlap of SKYLAB photography allows good to excellent stereoscopic study of relatively sharp images for the delineation of landforms, vegetation types and other events. Stereoscopic delineation from LANDSAT imagery is marginal at best, and often scenes imaged on different dates must be combined, for stereo and pseudo stereo models. Relief differences, an important consideration in the study of land forms, are obviously much better resolved using SKYLAB products.

The greatly increased resolution of ground features by SKYLAB as compared with LANDSAT is considered to be best in the S190B high resolution film, followed by S190A camera Stations 4, 5, and 6 respectively. It is unfortunate that no spring, summer or fall coverage of the S190B film was obtained, as more detailed studies of all disciplines could have been performed.

The results of the study of vegetation damage sites using data derived from S190A film were disappointing. Since color infrared photography is necessary for the detection of stressed, diseased or dead vegetation, the major cause of detection problems is the graininess of the S190A CIR film. The grains approach and surpass the size of damage areas three to four acres in size. The lack of leaf-on photography imaged by S190B winter scenes prohibited the direct evaluation of the earth terrain camera film for vegetation damage. However, based on the observed detail visible on the available winter coverage, the S190B camera would allow detection of damage sites as small as one

acre (Figure 19), and perhaps as small as one-fourth acre. This resolution would thus allow the detection, from SKYLAB earth terrain camera photography, of the majority of highway associated vegetation damage sites.

Good results were achieved for the hydrology-land use study. Both camera systems gave better agreement with the ground truth than did LANDSAT imagery. Better correlation with ground truth was achieved using the S190B CIR film than with S190A films, in spite of the fact that only winter S190A was available, but S190A CIR Color and B & W Panatomic-X films are also considered valuable for land use and vegetation type determinations. The land use/cover type data currently needed for hydrologic studies of large watersheds (over 1000 acres) can be adequately provided by S190A, S190B and LANDSAT-1 systems. LANDSAT imagery may not be capable of providing sufficient detail to fulfill projected future cover typing needs for environmental impact statements. Based on the limited study of winter S190B scenes, this film will provide all the necessary detail data for future requirements, and greatly minimize the need for extensive high altitude and conventional aircraft coverage currently used by the Maine Department of Transportation for the extraction of cover type data.

The most rewarding aspect of the SKYLAB study was the interpretation of surficial geology and glacial landforms data. Well-known areas were clearly visible in single scenes, and new insights into modes of occurrence and formation relationships were revealed. Several previously unmapped or unknown features were detected, especially in Eastern Coastal Maine, where their possible correlations to known formations were indicated. Winter S190A and S190B SKYLAB photography is superior to LANDSAT imagery, and temporal combinations of LANDSAT imagery, for landform identification, due to the enhancement effect of snow, shadows cast by low sun angles, and superior film resolution. Features having relief as low as ten feet are visible. Winter S190B CIR film is considered best for the eastern area study, where 2X enlargements approach the resolution of U-2

photography. Of the S190A films, stations 4 and 5 products have the best resolution for the detection of surficial features. Color film (Station 4) tends to have better interpretation capabilities than the black and white Panatomic-X films. Summer S190A photos imaging mature foliage are inadequate for good surficial delineations, and are inferior to LANDSAT imagery obtained in late fall or winter.

Surficial geologic studies utilizing conventional aerial photography and interpretation techniques are conducted by the Maine Bureau of Highways personnel for the location and evaluation of granular formations, and for mapping soil type boundaries as to their general engineering soils properties and characteristics. Existing United States Soils Conservation soils maps and any available geologic literature pertaining to the area of interest are referred to during a study, in conjunction with the large scale air photo coverage. Data derived from the study and interpretation of SKYLAB photography has provided insight to formational relationships in remote regions and additional knowledge in areas of mapped geology. More accurate placement of formation boundaries has been accomplished in areas previously mapped by reconnaissance methods.

Data derived from S190B photography is most suitable for developing geologic information. By projection methods, the photos can be enlarged to a suitable scale for the production of base maps, or for plotting interpretations at any convenient scale. The large areal coverage of a single frame allows synoptic regional viewing of a stereoscopic model, thereby increasing the ability to predict materials types within related formations.

In light of the knowledge gained in this study concerning SKYLAB S190A and S190B photography, it is clearly evident that the S190B earth terrain

camera photography is beneficial to our present needs, providing the detail necessary for adequate evaluations, with the color infrared format having the best utility for visual interpretation. The S190A film lacks the detail available in the S190B, and the multispectral photography adds only slightly to the data obtainable from S190A CIR products. The S190A system, however, is superior to the LANDSAT multispectral scanner system for visual interpretation of surficial geologic features.

In Maine there is a growing demand and need for land use/cover type data. Maps are presently being prepared primarily using RC-10 CIR photography, with data being compiled for towns and small regional districts. Typing for nearly half of the state, in the unorganized townships, could be adapted to LANDSAT or SKYLAB scenes. At present, cover type data requirements as to resolution for planning and/or zoning needs have not been defined to the point of indicating which satellite system would best provide the data. If S190B cloud-free coverage of the entire state were available, it would be adequate for most land use mapping, with significant cost benefits being realized.

APPENDIX

Visual Evaluation of SKYLAB Photography by Field Personnel

On the following nine pages are three sets of rapid, preliminary objective evaluations made by three observers, of features they could identify on various SKYLAB films and combinations by stereoscopic examination. Each observer was asked to look for features and events he knew to exist, as listed on sheets A, B, and C, and rate them according to an arbitrary standard, indicated below, on how well they could be observed or identified:

- 1 = Excellent
- 2 = Good
- 3 = Fair
- 4 = Not Detected

Observers 1 and 2 are regional field geologists having an intimate knowledge of most of the listed events within their specific areas, and were supplied with scenes that imaged their region of familiarity. Both observers have a good working knowledge of photo interpretation, but are not considered experts. Observer 3 has a good background in interpretation, and was less familiar with the regional terrain being analyzed, but had a broader familiarity with imagery, and used only winter photography.

The Camera Stations and combinations used for viewing indicate the stereopairs; i.e. 1/1 is a stereopair of station 1 photography and 3/4 indicates a stereopair utilizing a station 3 scene for the left eye and station 4 scene for the right eye. Film types are listed below, as described in "EREP INVESTIGATORS' DATA BOOK", October 1972:

S190A cameras utilize 70-mm film of a 4-mil base in cassettes holding approximately 400 frames each. Photographic format size is 2.25 inches square. The system is designed for the following bandwidth/film/filter combinations.

<u>Camera Station Number</u>	<u>Bandwidth Micrometers</u>	<u>Film (4 mil base)</u>	<u>Filter</u>
1	0.7 to 0.8	IR Aerographic B&W, type EK 2424	CC
2	0.8 to 0.9	IR Aerographic B&W, type EK 2424	DD
3	0.5 to 0.88	Aerochrome IR color, type SO 127	EE
4	0.4 to 0.7	Aerial color (high-resolution), type SO 356	FF
5	0.6 to 0.7	PANATOMIC-X Aerial B&W, type SO 022	BB
6	0.5 to 0.6	PANATOMIC-X Aerial B&W, type SO 022	AA
	0.5 to 0.88	Aerochrome IR color, type EK 3443 W-12	

ETC - Earth Terrain Camera (S190B)

Originally it was planned that the twenty-one and more possible combinations of films would be viewed by at least six observers. However, the logistics of getting field personnel into the office for the required time, and the limited funds available precluded such an ambitious undertaking. It is believed that this "pilot study" provides some insight into the visual analysis of the photography by relatively untrained observers, and the results are as might be expected from lengthy analysis of the film by the principal investigators.

No statistical approach to the data has been made, but a quick evaluation indicates the following:

- (1) The S190B (ETC) film was almost always considered best for the identification of most features and events, except where the winter scenes would obviously obscure features such as fields, water bodies, dynamic events, etc.

- (2) Large features were obviously easier for the observer to detect, and areas of high contrast, such as cut over forest plots and distinctly different adjacent forest and field areas.

Also to be considered are the degrees of visual acuity and expertise possessed by each observer. Observer one made the following comments and observations:

"CIR transparencies are difficult to use because they contain strong textural features." - "S190B is very good for topographic, morphological and geologic work." - "S190A CIR prints show shallow tidal waters better when backlighted, whereas S190A color prints show tidal waters better when toplighted. When the two are combined and lighted either way, tidal waters are easily seen."

Observer one found "no apparent advantage" for identification of terrain features in the following combinations: CIR/B & W, Color/B & W, Stations 5/1, 5/2, and 5/6.

Observer three, using only winter scenes of S190A and S190B, found many features completely obscured or not applicable within his viewing region.

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